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ON SOME EVIDENCES AS TO THE VERY EARLY USE OF IRON.

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From "Iron."

The more extended our inquiries become concerning the state of some, at least, of the arts in ancient times, so have they always resulted in indicating an ever-increasing rise towards excellence in the ultimate product, in proportion as the examples cited belong to ages more remote from our own times. This assertion may doubtless be questioned by some; yet, as a point upon which those who have investigated high archæology appear to be agreed, that just mentioned seems to stand out as settled.

Many proofs of this may be found, but it is sufficient to signalize at present one or two—such as the architecture and sculpture of Proto-Egypt, Assyria, India and Greece—which, it is well known, never have been equalled in subsequent ages. That the artificers employed in executing the most ancient examples of mechanical execution in Egypt, were possessed of iron tools, (and as I shall presently show, almost certainly steel) my former paper was in part directed to prove.*

That iron was used by the Chaldeans, we have substantial proofs, although the examples which have come down to us are small and few; yet that is not remarkable when we remember the quickly oxidizing character of this metal in comparison with copper, silver, gold, etc. The Rev. Henry Rawlinson, in his "Five Great Monarchies," vol. i, pp. 98, 99, says, in reference to the metallurgy of the Chaldeans: "Metal seems to be scarce, and not many kinds are found; there is no silver, zinc, or platinum, but only gold, copper, tin, lead, and *iron*." . . . "Iron, as already observed, is extremely uncommon, and when it occurs is chiefly used for the rings and bangles which seem to have been the favorite adornment of the people."

When, however, we do find relics of iron manufacture among the ruins of the Proto-Chaldean kingdom, which had its period of chief activity and importance between 2000 and 1500 B.C., few though they be, and doubtless but a part of a large number of original examples lost through oxidation, we are led to infer that these, such as they are, have reached us owing to some peculiarities of position, which have interfered with the natural tendency to rapidity of oxidation attaching to iron.

When the seat of the Mesopotamian empire moved northwestward up the Tigris, and the Assyrians were the ruling nation, the testimony of Layard is conclusive as to their knowledge of the utility of iron.† In his other work,‡ Layard speaks still

* "Iron," vol. i, p. 739.

† Layard's "Nineveh and its Remains," vol. i, p 351, *et seq.*

‡ "Nineveh and Babylon," p. 191, *et seq.*

more assuringly as to the degree of skill acquired, and the extent to which iron was used by the Assyrians. It would appear that the Assyrians were unable to give elegant forms or pleasing appearance to objects in iron alone, and that consequently they frequently combined bronze and iron. Numerous interesting specimens of this nature are included in the collection of the British Museum. Of one of these, the foot of a tripod stand, found at Nimroud, Dr. Percy has made a careful examination: "It was a small casting, in the shape of the foreleg of a bull. It formed the foot of a stand, consisting of a ring of iron, resting on three feet of bronze. It was deeply corroded in places, and posteriorly was fissured at the upper part. A section was made which disclosed a central piece of iron over which the bronze had been cast. At the upper part, where it had been broken off, the iron had rusted and so produced the crack above mentioned. The casting was sound, and the contact perfect between the iron and the surrounding bronze. It was evident, on inspection, that the bronze had been cast round the iron, and that the iron had not been let into the bronze; and in this opinion I am confirmed by Mr. Robinson, of Pimlico, who has had considerable experience in bronze casting.

	Composition.
Copper	88.37 per cent.
Tin.....	11.33 "

"Some interesting considerations are suggested by this specimen. The iron was employed either to economize the bronze, for the purpose of ornament, or because it was required in the construction. If the former, iron must have been much cheaper than bronze, and, therefore, probably more abundant than has generally been supposed. No satisfactory conclusion can be arrived at on this point, from the fact that bronze antiquities are much more frequently found than those of iron; for the obvious reason that bronze resists, much better than iron, destruction by oxidation. Although I think there are reasons for supposing that iron was more extensively used by the ancients than seems to be generally admitted, yet, in the specimens in question, it appears to me most probable that the iron was used because it was required in the construction. And if this be so, the Assyrians teach a lesson to many of our modern architects and others, who certainly do not always employ metals in accordance with their special properties. The instrument under consideration, it will be borne in mind, was one of the feet of a stand, composed of an iron ring resting upon vertical legs of bronze. A stand of this kind must have been designed to support weight, probably a large cauldron; and it is plain that the ring portion should, therefore, be made of the metal having the greatest *tenacity*, and the legs of metal adapted to sustain *vertical* or *superincumbent weight*. Now this combination of iron and bronze exactly fulfils the conditions required. I do not say that a ring of bronze might not have been made sufficiently strong to answer the purpose of the ring of iron; but I do say that, in that part of the instrument, iron is more fitly employed than bronze"

The feet of certain tripod stands found at Nimroud—these consisting of a circular ring raised upon feet, to hold jars and vases—are frequently represented on the bas-reliefs. Layard describes the ring of one of them as being of iron, bound in some places with copper, while the feet were partly of iron and partly of bronze ingeniously cast over it. The iron inclosed within the copper has not been exposed to the same decay as that detached from it, and will still take a polish. From the Egyptian character of the designs, Layard suggests that it may be inferred that some of them were not Assyrian, but had been brought from a foreign people, who he appears, and very satisfactorily, to conclude were the Sidonians and other inhabitants of the Phœnician coast, the most renowned workers in metal in the ancient world, and whose intermediate position between the two great nations he considers, may have been the cause of the existence of a mixed art among them. It should not be passed over either, that, according to Herodotus and Pausanias, the Lydian King Alyattes, who died about 570 B. C., among other offerings dedicated to his god an inlaid iron saucer.

As I have previously dwelt upon the use of iron among the early Egyptians, and have produced both literary as well as material evidence of that use, it is only necessary to cite the conclusion at which Mr. Basil Cooper arrived in respect of the antiquity of that use by them, from studies of a different order to those which I myself have more particularly pursued. He says:—"Turning to Egypt, we find that there also, as well as on the classical soil of Greece and Rome, the origin of the art of working

in iron is pushed back into the mythological and prehistoric age." We have no reason to doubt the testimony of Diodorus, when he repeats that the Egyptians assigned this invention also as well as all the other more important arts of life, to their great national culture divinity, Osiris. This, at least, implies that it was known among them from time immemorial.

I have already shown that the use of iron is identified with the time of erecting the oldest known Egyptian monuments, which, indeed, are by universal testimony proved to be the oldest on the earth; and, in view of the abundant evidence of a high yet peculiar civilization prevailing in that land in the remotest ages we can fathom, it has by many persons been assumed that most of the arts and sciences were spread therefrom among other peoples.

It is possible—nay, it is somewhat probable—that the knowledge possessed by the Proto-Egyptians of working in iron may have been brought with them from the Mesopotamian plains, whence they travelled westwards until finding the Nile Delta for a resting place. Yet, as bearing against that probability, we must remember that in the broad alluvial expanse, situate between the Euphrates and Tigris, they had not materials to work in, which demanded the use of iron or steel tools, such as they found when meeting with the Mukattam and nummulite limestones, syenites, porphories, diorites, and granites of the Nile valley. Yet, again, as strengthening the probability, we have the well-ascertained fact, that in the same alluvial soil the Proto-Chaldeans, and subsequently to them the Assyrians, practiced the art of working in numerous metals, including iron.

We may now pass down the stream of time to the Greeks, in the records of which people we find striking evidence of their acquaintance with the use and manufacture of iron. Indeed, as characteristic of that one-sided conceit which showed itself prominently through so many phases of the Greek mind, it is not surprising that, terming other nations "barbarians," the Greeks should attribute to themselves the discovery of iron, after the manner handed down to us in the Pelasgic tradition, connecting it with the Idæan Daktyls (Δάκτυλοι Ἰδαῖοι), professing that that discovery took place on the occasion of the burning of the forest which crowned their native mountain. The date of that conflagration, according to the Persian chronicle and other authorities, is the fifteenth century before the Christian era, or, more precisely, B. C. 1462.

Nor is the foregoing a solitary instance of literary testimony among the early Greeks as to their acquaintance with the metals. The shield of Achilles, described as of such excellent and intricate workmanship in the Homeric style, is another instance. While to Aristotle himself we are indebted for nothing less than an actual account of the mode in which the Greeks made steel in the fourth century B. C., proving them to have been acquainted with iron in the molten state also. The passage has been translated by Mr. Martin Lister, and reads thus:

"Wrought iron itself may be cast so as to be made liquid, and to harden again; and thus it is they are wont to make steel; for the scoria of iron subsides, and is purged off by the bottom; and when it is often defecated and made clean, this is steel. But this they do not often, because of the great waste, and because it loses much weight in refining; but iron is so much the more excellent the less recrement it has."

Somewhat obscure, no doubt, this Aristotelian passage is; yet when we carefully sift the nature of that which it conveys to us, it is replete with significance, as describing, very briefly and imperfectly, no doubt, what can scarcely be any other than a process of making steel used in Germany, certainly as late as the sixteenth century, that being proved by Agricola, who describes the process thus (*De re Metallica*, lib. ix.):—"Make choice of iron that is apt to melt and get hard, and may easily be wrought with the hammer; for though iron which is made of vitriolic ore, may melt, yet it is soft, or brittle, or eager. Heat a parcel of such iron red hot and cut into small pieces and then mix it with a sort of stone which easily melts; then set in the smith's forge or hearth, a crucible, or dish of crucible metal a foot and a half broad, and a foot deep; fill the dish with good charcoal, and compass the dish about with loose stones to keep in the mixture of stone and pieces of iron. As soon as the coal is thoroughly kindled, and the dish red hot, give the blast and let the workman put on, by little and little, all the mixture of iron and stone he designs. When it is melted, let him thrust into the middle of it three or four more pieces of

iron, and boil them therein five or six hours with a brisk fire; and, putting in his rod, let him often stir the melted iron that the pieces may imbibe the smaller particles of the melted iron, which particles consume and thin the grosser ores of the iron pieces, acting like a ferment to them, and making them tender. Let the workman now take one of the pieces out of the fire, and put it under the great hammer, to be drawn out into bars and wrought; and then, hot as it is, plunge it into cold water. Thus tempered, let him again work it on the anvil, and break it; and viewing the fragments, let him consider whether it looks like iron in any part of it, or be wholly condensed and turned into steel. Then let the piece be all wrought into bars; which done, give a fresh blast to the mixture, adding a little fresh matter to it instead of that which had been drunk up by the pieces of iron, which will refresh and strengthen the remainder, and make still purer the pieces of iron again put into the dish; every which piece let him, as soon as it is red hot, beat into a bar on the anvil, and cast it, hot as it is, into cold water. And thus iron is made into steel, which is much harder and whiter than iron."

The same process was also in use in the Island of Elba as late as A. D. 1683 (Kircher); and this place has been famous from the time of the Roman Empire for the production of steel.

From all the evidence we are led to infer that probably for about 3700 years the production of steel by immersing bars of wrought iron into a molten carburet of iron, was practiced among the nations in their progress westward—brought from Egypt, almost to a certainty, by the Greeks—established by them in the Mediterranean countries they occupied—whence it was acquired by the Romans, and by them introduced into their vast western empire.

From what Pliny had observed, and has handed down to us (lib. xxxiv., c. 14), it appears that the Romans in his time (*i. e.* in the earlier half of the first century of our era) were well versed in the practice of steel making by the same process; and seeing that he held the office of Spanish Procurator under Vespasian, it is at least very probable that his observations were made on the mode of manufacture established by the Romans in that country, wherein Toledo has been a famed seat for the production of swords of unrivalled temper and elasticity, from the time of the Romans until now. (I believe I am correct in stating, on the authority of Mr. Cockburn Muir, C. E., who has visited the place, that the Spaniards keep secret at the present time, the process by which their steel is made.) Toledo is a place well worthy of mention in these inquiries, seeing that the Roman army was provided with steel swords, many of them made here, with which they conquered the greater part of the known world, including these British Isles of ours, under Cæsar, B. C. 55.

When the archæology of India and China shall have been penetrated to its depth, we may hope to arrive at something more definite in respect of the practice in very ancient times of the art of iron-making; until that is done, much ignorance thereon is inevitable, and in view of what little knowledge we do even now possess, from the sparse nature of the information to our hand, even concerning comparatively late periods, we are led to hope for a great deal when the complete sources of testimony are bared to our vision.

A brief review of what we have already ascertained should be sufficient to convince the most skeptical how ignorant we are of the stages through which metal urgy has passed in the East; and in regard to this state of things Mr. Mallet has so well written, that I cannot do better than quote his *ipsissima verba*: "It is strange that of the iron metallurgy of Asia, the motherland of all the arts; of India, the country where, more than twenty centuries ago, King Parus presented to Alexander the Great, a *packa*, or wrought bar of Damascene steel, just as Homer's Achilles offered for a prize at the games of Patroclus, a like valued mass, whence the Greeks obtained the like 'wonder-working sword blades,' *θαυμασια ξιφη* where steel dies were employed for coinage, when our ancestors were naked savages (I presume Mr. Mallet means "the ancient Britons," who were not our ancestors); of China, whence cast iron hollow vessels now reach us of a combined magnitude and thinness that we have not yet been able to imitate, or even imagine the process by which they have been cast, and razor steel said to surpass all European steel in temper and durability of edge; less is known than of the iron working of any other part of the civilized world—yet such is the fact.

"Central Asia, and even China, as yet

are nearly *terræ incognitæ*; but India, south of the Himalayas, has been more or less open to European observation for centuries, and has been in our own power for more than one. How little is known of the working of iron in China may be gathered from the bald and imperfect account of it given by MM. Stanislas Julien. Memb. Inst., and Paul Champion, Preparateur au Conserv. des Arts et Metiers, in their work on the 'Technical Arts of the Chinese Empire,' published in Paris in 1869; the first-named author, having a reputation as one of the first Chinese scholars in Europe; and the second being a competent metallurgist and technologist. Yet China possesses the knowledge of working in fluid cast iron, as well as in wrought iron and steel—the first being, at the present day at least, commonly reported to be unknown in India, where wrought iron is made direct from the ore, and steel also."

Judging from what we gather among the mountains of India, the working in iron in very large masses was carried on there many centuries since, for at the mosque of Kuttub Shaw, in or near Delhi, is standing at this very day an iron column which is described by Colonel A. Cunningham in the archæological report to the Government of India for 1861-2.

"Art. 65. The Delhi pillar is a solid shaft of mixed metal upwards of sixteen inches in diameter, and about fifty feet in length. It is true there are flaws in many parts, which show that the casting is imperfect; but when we consider the extreme difficulty of manufacturing a pillar of such vast dimensions, our wonder will not be diminished by knowing that the casting of the bar is defective. The total height of the pillar above ground is 22 ft., but the smooth shaft is only 15 ft., the capital being 3½ ft., and the rough part of the shaft below also 3½ ft. But its depth underground is considerably greater than its height above ground, as a recent excavation was carried down to 26 ft. without reaching the foundation on which the pillar rests. The whole length of the iron pillar is therefore upwards of 48 ft., but how much more is not known, although it must be considerable, as the pillar is said not to have been loosened by the excavation. I think, therefore, it is highly probable that the whole length is not less than 60 ft. The lower diameter of the shaft is 16.4 in., and the upper diameter is 12 05 in., the diameter being .29 of an in. per foot. The pillar contains about 80 cubic feet of metal, and weighs upwards of 17 tons."

With regard, then, to the constitution of the metal of which this remarkable shaft is composed, Colonel Cunningham erroneously described it as "cast metal;" and it does not appear on the face of his report that he personally examined the shaft itself, but probably relied upon what was conveyed to him by others, guided, possibly to some extent, by the very mystifying account given of it by Mr. James Furgusson in his "History of Architecture," vol. ii, p 460, where the column is described in one line as "wrought iron," and in another as a "single casting."

There is much confusion in the different accounts I have met with as to the precise building in which the iron column is situated. The column itself is usually called "Kuttub Minar," yet according to the account in the "Asiatic Researches," vol. iv., p. 727, by Ensign J. T. Blunt, the "Kuttub Minar" is a stone building between 240 and 250 ft. high, built by the Emperor Shaw Jehan in the present city of Delhi; and it appears from this account that the minar—minaret—was erected at the expense of Kuttub Shaw, whose tomb is situated a few hundred yards westward of the minar.

This Kuttub Shaw came to the throne of Delhi in the Mussulman year 602, corresponding with the Christian era 1205; but the iron column itself is vastly older than this stone building, as will be seen hereafter. It is specially desirable that the confusion which exists on this point should be cleared up; and, by way of anticipating what is probably the fact, we may presume that the column, pillar, or Laht referred to, is within the precincts of the enormous, never-completed, still unfinished mosque, named after the founder of the aforesaid stone minar.

I am much indebted to Colonel H. Yule for a sketch of this remarkable Laht, and also for valuable references to the literature bearing upon it. In a letter to me he says, "There is an inscription on it ascribing its erection to an otherwise unknown Raja Dhaoa. The character of the letters is considered both by Prinsep and Cunningham, to refer it to the third or fourth century of our era. It also bears later inscriptions. Prinsep calls it a 'monument of skill in *forging* iron, for the pillar is a well-wrought circular shaft of iron of considerable mag-

nitude.' Cunningham again speaks of it as if it were *cast*. It is a pity the thing is left so obscure. I have seen the pillar twice or thrice, and it certainly seemed to me a shaft of wrought iron to all outward appearance. But, query, whether, if it were really iron, the surface could have remained as perfect as it is—polished, and bearing the superficial inscriptions—for 1600 years?

"It is mentioned by the Arab traveler, Ibn Batata, who was at Delhi *circa* 1340. He says: 'In the middle of the mosque you see an enormous pillar, made of some unknown metal. One of the learned Indians told me it was what is called *Haft ush*, *i.e.*, 'seven metals,' being compounded of so many different metals. The pillar has been polished on a surface about as long as one's forefinger, and this part shines brilliantly. Iron leaves no marks upon it. Its length is thirty cubics; we encircled it with the cloth of a turban, and found the girth so measured to be 8 cubits.' The Arab's *girth* is greatly exaggerated; so probably his *length* is also an exaggeration of the height above ground, and bears no reference to the actual entire length, which we see to be more than 30 cubits."

With the object of deciding whether the iron was "cast" or "wrought," a fragment has been cut from the pillar, and not long since sent to England, a portion of which is said to have passed into Dr. Percy's hands; and this he (Dr. Percy) had heated and drawn out on an anvil, after which he (Dr. Percy) pronounced it to be forged "iron."

Strangely divergent, however, from the account given by Colonel Cunningham (already quoted), is that which has appeared in the "Journal of the Iron and Steel Institute," where, on the authority of Lieutenant Spratt, R. E., said to have been stationed at Delhi, certain statements are published which are utterly contradictory of those given by Colonel Cunningham. Whether in the main Colonel Cunningham's account or that of Lieutenant Spratt be correct, I am not at present in a position to determine. I am, nevertheless, bound to point out that in dealing with the question, either Lieutenant Spratt or Mr. David Forbes, F.R.S. (the writer of the Iron and Steel Institute's Report), is at fault in respect of his representation of that which Colonel Cunningham has really written.

One or other of these gentlemen ["Iron and Steel Institute Journal," vol. i., p. 151] represents Colonel Cunningham to have reported, and Mr. Mallet to have repeated, that the above-ground height of the column was 48 ft.; whereas in both Colonel Cunningham's report and Mr. Mallet's account, that is the total height of both the above-ground portion and that below ground, to the depth reported to have been excavated; but now, according to Lieutenant Spratt, the above-ground portion is 24 ft., or 2 ft. higher than that portion is reported by Colonel Cunningham, while in regard to the below-ground portion, it is not only very short indeed, but of a complex character, contrasting strangely and irreconcilably with the description handed to us by Colonel Cunningham.

The account to which I allude reads thus: "The height of the column above ground is only 24 ft., and 3 ft. below ground it ends in a bulb like an onion, which is held in its place by eight thick rods of iron, on which it rests, and which at their lower extremity are let into blocks of stone in which they are secured by lead. The iron of which it is made, which appears to have been originally in blooms of about 50 lbs. weight each, has been examined by Dr. Murray Thomson, of the College at Roorkee, who found it to be wrought iron, possessing a specific gravity of 7.66."

With respect to the material of which the pillar, alleged to be one and the same, to which both the afore-mentioned reports appertain, is composed, they agree; but it inconceivable that an officer and archæological surveyor to the Government of India of Colonel Cunningham's reputation, could be so far led away from facts as to report, certainly the most remarkable relic of ancient iron metallurgy yet discovered, in the loose and false style he clearly has done, if Lieutenant Spratt's account be the correct one.

The discrepancies to which I have directed attention certainly suggest the possibility of two different iron pillars existing in or near the city of Delhi, and that some confusion has resulted on that account; but as we have at present no certain evidence of more than one such column, and considering the complex, and really, even now-a-days, most-difficult-to-produce character of the forging, as it is described by Lieutenant Spratt, we must, in the absence of more precise information—in view, too, of the palpable blunders in the report of the Iron and Steel Institute as to Colonel Cunning-

ham's statements—prefer Colonel Cunningham's account, as being most probably nearer the truth.

Having thus, I trust, judged impartially in respect to the real form of this monument, the next point we have to deal with is the date of its construction. For this I again refer to Colonel Cunningham's report, Art 66, *et seq.*, in which he concludes for that event the year 319 A.D.

"66. The iron pillar records its own history in a deeply cut Sanskrit inscription of six lines on its western face. The inscription has been translated by James Prinsep, who remarks that, 'the pillar is called the arm of fame of Raja *Dhava*, and the letters cut upon it are called the typical cuts inflicted on his enemies by his sword, writing his immortal fame.' It is stated that he subdued a people on the *Sindhu* named *Vahlikas*, who must be the *Bahikas* of the Panjab; and, lastly, that he obtained with his own arm an undivided sovereignty on the earth for a long period.' The above is the whole of the meagre information that can be gathered from this inscription, save the bare fact that the Raja was a worshipper of Vishnu. The date of the inscription is referred by James Prinsep to the third or fourth century after Christ; but Mr. Thomas considers that this is 'too high an antiquity for the style of the writing employed on the monument.' I agree, however, with Prinsep, as the characters appear to me to be exactly the same as those of the Gupta inscriptions. I have already suggested the year A.D. 319, which is the initial point of the Balabhi or Gupta era, as an approximate date for Raja *Dhava*, as I think it not improbable that he may have assisted in the downfall of the powerful Gupta dynasty.

"According to universal tradition, the iron pillar was founded by *Bilan Deo*, or Anang Pal, the founder of the Tomara dynasty, who was assured by a learned Brahman that, as the foot of the pillar had been driven so deep into the ground that it rested on the head of *Vásuki*, king of the serpents, who supports the earth, it was now immovable, and that dominion would remain in his family as long as the pillar stood. But the Raja doubting the truth of the Brahman's statement, ordered the pillar to be dug up, when the foot of it was found wet with the blood of the serpent king, whose head it had pierced. Regretting his unbelief, the iron pillar was again raised; but owing to his former incredulity, every plan now failed in fixing it firmly, and in spite of all his efforts it still remained loose (*dhila*) in the ground; and this is said to have been the origin of the name of the ancient city of *Dhili*.

"This tradition has been variously reported by different authorities, but the main points are the same in all. . . The popular belief in this tradition is confirmed by the well know verse:

Killi to dhilli bhai,
Tomar bhaya mat hin.
The pillar became loose by Tomar's folly.

Kharg Rai relates this tradition in a more poetical form, making the date the Samvat year 792, or A. D. 736."

With further respect to this column, several writers appear to have confounded it with the stone column, known as Feroze Shah's Laht, described in the "Asiatic Researches," vol. i., p. 371, as the following will show:

"At ancient Delhi," says Bacon, "there is an extraordinary pillar, apparently metallic, but is really of red sandstone, bearing a silvery bed in it, now called Feroze Shah's Laht, or walking stick. *Thirty feet of it are above-ground*, and buried many feet in the earth. There is one exactly similar to this at the Cootub Minar, and another at Allahabad. All are supposed to be of the same origin, but their history is quite lost in obscurity. They are covered with inscriptions. Forrest mentions that this pillar at the Cootah Tower is of solid iron, and that the whole temple is a subject of great doubt and incertitude."

A learned correspondent, too, writes me in respect of this iron column: "The inscriptions thereon are of *different dates*. Some, the most ancient in Ragari letters, others in Sanskrit, all prefaced by the mystical Holy Invocation O'M. The events engraven involve very great periods, thus one is decidedly the year of Christ 67 (by computation).

If this last account then has reference to the column described by Colonel Cunningham, (which I am bound to say I doubt), it is unquestionably much older than he concludes. I am of opinion, however, that it relates to the red stone Laht of Feroze Shah, and, therefore, has no reference to the iron column. In the midst of such conflicting or rather confused testimony, which is all we yet possess, I conceive it would be unwarrantable to attempt to fix the date of

this remarkable work. The utmost then at which we can now arrive is, that its antiquity is very considerable. This conclusion being arrived at not only by reason of the absence of any precise generally current information regarding it, but judged of also from the universal testimony throughout the East, both in material and literary relics, of a very remote and, contemperaneously, very high intellectuality then prevailing.

As to how this remarkable forging was produced, some have been bold enough to conjecture. For the present I abstain from offering an opinion, but as a suggestion, indicating what may be at least a probable mode in which large pieces of iron were produced in ancient times, I refer to the account presented to us by Mr. Alfred Russel Wallace, of the manner of producing the "sacred krisses" in the Island of Lombock.

These were made at taking of a census, the Rajah commanding a needle to be brought him from each head of the population. These needles were collected by the chiefs in the various villages and towns, and a bundle sent from each to the Rajah, which contained a number of needles corresponding to the number of the people; and when it was quite certain that every village had sent in its bundle, the Rajah divided the needles into twelve equal parts, ordered the best steel worker in Mataram to bring his forge, his bellows, and his hammer to the palace, and to make twelve krisses under the Rajah's eye, and in sight of all men who chose to see it.

Whether, then, the iron column at Delhi is the result of taking a census after the manner adopted by the Rajah of Lombock, I must leave to others to determine; but that it is a monument in commemoration of some grand event, or of some high religious belief and practice, no one, I presume, will attempt to question.

Mr. Mallet, after carefully reviewing the evidence as to whether this huge specimen of ancient ironwork be a casting or a forging, says:

"We are thus obliged to consider that this pillar is not a casting, but a huge forging in native Indian or other Asiatic-made wrought iron, and if so, the question arises how was it forged? We have no evidence that 'blooms' of more than 90 lbs. or 100 lbs. each were ever made by modern methods; these would be too small to build up singly into a bar of 16 inches diameter. It is, however, conceivable that such little 'billets' as were procurable from such blooms might be welded into bars, and these bars made into a faggot, out of which such a bar, by sufficient means for bringing it to a welding heat, and for then hammering it, might be welded into a cylindrical bar such as that of this iron pillar.

"Now, the limit to the size of a faggot that can be welded with given means of heating it, is found to be when the mass is so great in proportion to the power of the furnace that the exterior of the mass, when the heat is being applied, oxidizes and melts away (owing to the slowness of heating, and hence long continued exposure to the heat) as fast as piece after piece is laid on to make up for the waste.

"This limit has been reached before now even in our best reverberatory forge furnaces; it actually was touched upon at Liverpool, in forging the Mersey Company's great 12-inch gun. Unless, therefore, the ironworkers of India, between the third and fourth century, A. D., possessed air-furnaces and lofty stalks or blowing apparatus of some sort, upon a scale now unknown, and, indeed, not conceivable in any form of native apparatus, we may confidently affirm that no faggot to form a welded bar of 16 in. diameter could have been by any possibility brought to the welding heat at all, or without such waste as to prevent it ever being forged.

"If we pass from the heating of such a bar to the forging of it, our difficulties are still greater. The limit in size of *hand-forged* work in Europe was about reached in the production, in days gone by, of the heaviest 'best bower' anchor of a ship of the line. The largest section of the anchor shank, when welded to the arms, was about 8 in., or perhaps 9 in. across, and the welding was effected by the blows of twenty-four 'strikers,' trained to strike in time, and swinging 14-lb. to 28-lb. sledges. The shower of blows dealt for some minutes' spell upon the mass of iron of this large section produced a very insignificant effect, so that both the faggoting and the welding of such anchors were often very defective, and the strikers having to stand close in a ring, within the short distance for swinging the sledge from the glowing iron, were greatly scorched by its radiated heat, and some with fine skins were unfitted for the work. Hereabouts, then, the limit to

hand-forging was reached, both as to the power of the hand-sledge to act upon the mass of iron, and as respected the power of the men to endure the heat radiated from the glowing iron at the short distance from it, limited by the length of the handle of a sledge when swinging.

Now, the section of the shank of a "best bower" of 8 or 9 in. diameter, is to that of the Delhi iron pillar, about as 64 to 201—*i. e.*, the latter would radiate from its heated extremity more than thrice as much heat, and an equal length would be more than thrice as great a mass to be dealt with by the sledge-hammer, than in the case of the anchor. We may, therefore, affirm that, even in European hands, a bar of wrought iron of 11 in. diameter could not be welded up by hand labor with the sledge. The latter would produce no adequate impression—least of all in the comparatively feeble hands of Asiatics—and human skin and muscles could not withstand, at five or six feet off, the intolerable glare and scorching of such a mass heated to the welding point.

How then was the Delhi pillar forged in India, even assuming that some means for heating it existed? Forging by power in some form of course suggests itself, but upon what source of power can we even speculate? Human muscles, and the "bullock walk" by which the water-skins, or "bheesites," are drawn up from the wells or tanks, appear to be the only present sources of power in India.

The water-wheel, or *noria*, for raising water by the application of such animal power is common; but the production of power by the descent of water on a wheel seems never to have been known in India, where, indeed, except in the hill districts, no falls for water-power exist. The windmill, though said to have been known in Persia from some very remote period, has never been seen in India, and it need scarcely be said steam-power is out of the question.

It is barely imaginable that some form of falling tup-hammer raised by men acting by ropes, after the manner of the old singing-engine for pile-driving, may have been employed, or some rude form of tup or tilt-hammer, moved by bullocks, acting on a walking-wheel. It is for Indian archæologists to discover if there be any records or traditions of such appliances, without which the methods by which this huge pillar was forged must remain inexplicable.

The pillar itself stands before us, so far, a metallurgical enigma. If it stood alone, and were this great ancient forging in wrought iron alone known to exist in India, we might pass it by, content to suppose it too isolated an instance on which to found any conclusions as to the iron metallurgy of that country in former ages; but, although little noticed, and apparently quite unknown to our European writers on iron metallurgy, other examples likewise exist.

Not to lay any stress on the probable existence in India of other iron pillars, as affirmed to the writer by an accurate Indian officer well acquainted with the country, the following facts are recorded by Mr. James Fergusson in his "Illustrations of Ancient Architecture in Hindostan:"—

"In the Temple of Kanaruc, or Black Pagoda, in the Madras Presidency, the walls of the *mantapa*, or porch (which is about 60 ft. square inside) are about 10 ft. in thickness, and the depth of the doorways is, consequently 20 ft., and their lintels are supported by large iron beams of about 1 foot section laid across from side to side. The roof is formed after the usual bracket-fashion of the Hindus, each course projecting beyond the other, so as to give (from the inside) the appearance of inverted stairs. . . At about half the height, where its dimensions narrow to about 20 ft., a false roof has been thrown across, the remains of which now lie heaped up as they fell on the floor of the apartment. Among them may still be remarked several beams of wrought iron about 21 ft. in length and 8 in. section, and a great many blocks of stone 15 ft. and 16 ft. long (and they were probably broken in their fall), and of a section 6 ft. by 2 ft. or 3 ft." Here then, we have employed as mere building material wrought iron bars of 8 ins. square and 21 ft. long. Mr. Fergusson views this temple as having been built between A. D. 1236 and A. D. 1241.

In another temple examined and described by Mr. Fergusson—that of Mahavellipore, standing alone on a solitary rock of granite projecting into the very surf on the coast, near Madras, and the date of which he refers to the tenth or eleventh century, A. D., but which he deems may be as late as the thirteenth or forteenth century (described in his great work as above, p. 57, and plate viii.)—he informs me

there are empty sockets for beams, like those just noticed; the beams, he justly argues, must have been of iron, as the sockets show a scantling, which would have been, if in timber, perfectly useless under the load carried.

It is highly probable that at Kanaruc the ceiling beams thrust themselves out of their sockets by alternate expansion and contraction, and so brought down the "false roof," as the filling above is called; but the place affords a bad foundation, and is said to be subject to earthquakes. However, our business with these iron beams is simply as metallurgic monuments. Here then, we have the fact, that at Delhi in the north, and at Madras, in the far south of India, massive forgings exist, such as all Asia, so far as we know, could not produce at the present day, and of a size rivalling those upon which Europe to-day prides itself.

The earliest of these dates from the third or fourth century, and the latest from the eleventh to the fourteenth centuries of our era. With such an interval of time as 900 to 1000 years, and such a diffusion in space as from north to south of India, it seems impossible not to conclude that the evidence of these monuments attests the existence in India for that long period of a great iron manufacture, well established, and with a relative cheapness and certainty of product that admitted of the use of iron as a material for public monuments, and as a building material in sacred edifices, and that this manufacture was extinct, and the art and methods lost, long before any modern European occupation of India. So that far from Indian iron-working having been from time immemorial the same feeble thing we see it to-day, it was once a great and flourishing craft, and extended over parts of the entire Indian peninsula.

Nothing heretofore brought to light in the history of metallurgy seems more striking, to the reason as well as the imagination, that this fact: that from the remote time when Hengist was ruling in Kent, and Cerdic landing to plunder our barbarous ancestors in Sussex, down to that of our Third Henry, while all Europe was in the worst darkness and confusion of the Middle Ages—when the largest and best forging producible in Christendom was an axe, or a sword-blade—these ancient people of India, the forerunners of those now so enfeebled and so degraded, possessed a great iron manufacture, whose products Europe, even half a century ago, could not have equalled.

Yet these conclusions rest on no new facts, but on the colligation of old ones by the light of practical knowledge. Indian archæologists and writers have long known of the existence of these iron monuments of an ancient and lost art in India, but their importance has, the writer believes, not before been recognized as bearing on ancient oriental metallurgy. The reason of this is, that those who have examined the monuments of India, however scholarly and able in many ways, have not been metallurgists, and have had no practical knowledge of iron working. The ancient, and indeed the existing technology, at large of India—still more of Asia at large—remains almost unexplored and undescribed; and whenever it shall be examined, analyzed, and described by really competent men, (and such have never yet been commissioned with the task), results even more strange, and perhaps of more importance, historical and practical, than those deducible from the Delhi iron pillar, will, no doubt, come to light.

A notice by M. Lévog, a mining engineer resident in Japan, of the iron-workinig districts of that country, may throw some light on the conjectural modes by which these great forgings may have been effected by human power in these remote ages in India.

In reference to the mode of iron-working in the mining province of Ykouno, M. Lévog says:—"The treatment employed is a sort of imperfect Catalan method . . . . . but what distinguishes the Japanese method from that of Ariege is, that they treat at once 16,000 kilos. of ore, and produce an enormously long pig of 1300 kilos., which is broken up under a huge hammer, constructed after the style of a pile-driving ram, to which motion is given by a walking-wheel of 11.5 metres diameter, acted upon by men. One can see that potent blows may thus be given, but their frequency and regularity do not seem such as to admit of a forging being thus produced, even if the means for heating a mass as huge as those referred to were capable of being guessed at." Thus far, Mr. Mallet.

With respect to the evidence which the literature of the ancient world has to offer in proof of the extreme antiquity of the use of iron, that evidence is considerable and wide-spread; and as the region of research has already been so extensively explored by

the learned and cultivated Goguet, I shall content myself with now briefly running through what he has collected.

He says:—"The invention of the hammer, anvil, and pincers, was placed by the ancients in the remotest ages. The Egyptians attributed these inventions to Vulcan, others gave this honor to Cyrinas, the father of Adonis (Pliny, 1. 7, section 57), which makes them no less ancient."

I may here remark, that this worship of Vulcan was well established, particularly in Egypt, at Athens, and at Rome. His forges were supposed to be under Mount Ætna, in Sicily. Vulcan was generally represented as covered with perspiration, blowing with his arm the fires of his forges, at other times holding a hammer raised in the air ready to strike, while with the other hand he turned with pincers a thunderbolt on an anvil.

Goguet continues:—"The art of forging metals, without any doubt, was known in Egypt, and some parts of Asia, in the most distant times. We see arms of metal in use in Palestine, a few ages after the Flood. Moses says that Abraham drew his sabre to sacrifice his son Isaac. The ancient Patriarchs shearing their sheep is a further proof that the fabricating of metals was then well understood. They knew even then how to execute works in gold and silver, which require delicacy and exactness. In a word, we see everything relating to metals, the places where they are found, the manner in which they are wrought, etc., exactly described in the book of Job."

Arguing as a pure rationalist, and as one unacquainted with the practice of working in metals, Goguet is here led off into that favorite but mistaken theory which has taken firm hold upon the minds of those who are versed in the literature only of metallurgy, and he proceeds to argue that *ex necessitate*, mankind would begin to work with "such metals as were most easily procured and fabricated," and he cites gold, silver, and copper as examples, because "considerable masses of these metals were sometimes found pure and without mixture," and "that they were easily melted and refined. For these reasons," he says, gold, silver, and copper were the first metals that were wrought;" and he adds, "but the finding and working of iron must have been a very late and difficult discovery. Without doubt, it was the last of all the metals mankind were acquainted with, or knew how to use.....In reality, the greatest obstacle to the use of iron was the difficulty of making it. Iron, of all metals, is the most difficult to bring into fusion.

In these very words and some others which occur in M. Goguet, bk. ii. chap 4, entitled, "Of the Discovery and Working of Metals," we find nothing less than the identical doctrine propounded in France more than a century ago, which has been revived in these latter days, namely, that of the successive use by man of stone, bronze, and iron, and which has received the support of so many and such noted persons.

That this doctrine is untenable, I have shown in a former paper; and as to the difficulty started by those who argue from mere book knowledge, I have already pointed out from the facts of metallurgical science, that fusion is not essential to the reduction of iron into the metallic state—that, in fact, to reduce it is one of the simplest and most readily occurring results in the whole range of metallurgic art, that, in fact, the most wide-spread practice of reducing iron is effected without fusion.

As if to make the difficulty set up concerning the necessity of fusing iron in order to work with it and convert it into tools, weapons, etc., still greater, Goguet, as if following after or leading on the *litterateurs*, adds, "Besides one single melting is sufficient to render gold, silver, or copper, ductile or malleable. It is not so with iron. A piece of this metal once melted is as untractable as ever, and not more ductile than a flint. In this state it is hard and brittle, and cannot bear the hammer either cold or hot. The file, the chisel, and the graver, can make no impression upon it. In order to forge iron, therefore, it was necessary to find out the art of softening it, and rendering it ductile. To do this, it must be melted a second time, then beat with very heavy hammers; this mass must be put in the furnace and heated till it is upon the point of fusion, then put again in this state under the hammer; this operation must be repeated several times; at last this hard and brittle mass, by frequent heating and hammering, becomes forgeable."

And yet, M. Goguet, with all this plausible argument against an extremely ancient use of iron, in the end finds it insufficient and directly contrary to the evidence with which he has dealt, so that he concludes his researches in the following words:

"In maintaining, however, that copper originally supplied the place of iron, I do not pretend to affirm that the last metal was altogether unknown in the ages we are now upon. Several testimonies give us reason to believe that some nations knew the art of working iron in very ancient times. There was a tradition among the Egyptians (already mentioned) that Vulcan taught them to forge arms of iron. (Chron. Pascal, p. 45, C.; Cedren., fol. 19 D.) There is a manifest contradiction in Cedrenus. For after he has said that Vulcan taught the Egyptians to forge arms of iron, he adds that, having obtained pincers by his prayers from heaven he used them in working copper. The Phœnicians also ranked among their most ancient heroes two brothers who were supposed to have discovered iron, and the manner of working it. (Sanchon, *apud* Euseb., p. 35.)

The Cretans, as Diodorus relates, placed both the discovery of iron and the art of working it in the remote periods of their history. The inhabitants of Mount Ida pretended to have learned the art of working this metal from the mother of the gods. (Sophocl. *apud* Strabo, l. 10; Diod. l. 17.) In a word, Prometheus, in Æschylus, boasts of having taught mankind the fabrication of all metals.

"Some authors ascribe the discovery of the art of working iron to the Cyclops (Pliny, i. 7, sect, 57) and some to the Chalybes (Ammian, Marcell., l. 22, cap. 8; Schol. Apollon. *ad.* l. 2), a very ancient people, renowned for their skill in working this metal (Virg. Georg. l. 1, v. 58; Æschyl., 'In Prom vinct.,' v. 501). The Chalybes inhabited the south coasts of the Euxine sea between Colchis and Paphlagonia. Clemens Alexandrinus pretends that the art of making iron malleable was found out by the Noropes. This nation was situated in Pannonia, along the banks of the Danube, between Noricum and Mæsia.

"Without entering into any discussion of these traditions, which are all beset with great difficulties and contradictions, it appears, from the Book of Job, that the art of working iron was known in some countries long before the ages we are now speaking of (Job, chap. xix, 23, 24: 'O that my words were now written! O that they were printed in a book! That they were graven with an iron pen and lead in the rock forever!' Chap. xx. 24: 'He shall flee from the iron weapon, and the bow of steel shall strike him through.' Chap. xxviii. v. 2: 'Iron is taken out of the earth, and brass is molten out of the stone.' Chap. xl. v. 18: 'His bones are as strong pieces of brass; his bones are like bars of iron.' And chap. xl. 27.)

"The books of Moses also furnish us with very strong proof of the antiquity of this discovery. From the manner in which this legislator speaks of iron, it appears that that metal must have been in use in Egypt long before his time. He celebrates the hardness of it (Lev. xxvi. 19; Deut. xxviii. 23 and 48), and take notice that the bedstead of Og, King of Bashan, was of iron; he speaks of mines of iron (Deut. viii. 9: 'A land whose stones are iron, and out of whose hills thou mayest dig brass'); he compares the severity of the servitude of the Israelites in Egypt to the heat of a furnace for smelting that metal (Deut. iv. 20). But what is most worthy of our attention is that they then made swords (Numb. xxxv. 16), knives (Lev. i. 17), axes (Deut. xix. 5), and tools for cutting stones (Deut. xxvii. 5), of iron. To make the blades of swords and knives they must have known the arts of tempering and turning iron into steel. These facts seem to me sufficient to prove that the discovery of iron, and the arts of working it, were extremely ancient in Egypt and Palestine."

After all, then, that has been advanced, I unhesitatingly ask, are not the proofs both literary and material which have been now (I believe for the first time) collected together, corroborative of each other? Do they not demonstrate that in the very earliest ages we can fathom, iron was used and well known? Relying upon the Hebrew records, it is thoroughly attested that very many (possibly all) of the metals were used simultaneously in the very earliest ages. That numerous other proofs are in existence I have little doubt, but I must leave their collection to others having more leisure than has fallen to my lot. I do hope that I have at least demonstrated, in respect to this one particular material, how pre-eminently unsafe it is in drawing conclusions as to the state of arts in remote past ages, to assume as universal that which appears at most as probable only, from the material relics met with in some countries only.

I am further bound to say, that those who have so concluded in modern times, seem to disregard altogether what ancient authors have recorded, thinking only to

satisfy some favorite theory. Such procedure is not only blinding at the first, not only never can evolve the truth, but must inevitably tend further and further from that sublime region.

In conclusion, I feel that I cannot express what I wish finally to convey, as the issue to which the investigation points, more fitly than in the words of my cultivated and talented correspondent. Mr. Robert Mallet, F. R. S., who in writing to me on the subject of ancient ironwork, says:—"It is a subject on which the usual, if not orthodox, views of achæologists generally seem to me as very superficial. They all seem to forget that at all times, as now, civilization was simultaneously at various stages in different parts of the world. When flints were the best tools of northwest Europe, iron and steel may have been those of peoples far to the east. As in palæontology, you can fix no horizon common to all the world at any time."

Dr. Percy, one of the foremost living authorities on the metallurgy of iron, in writing to me from the House of Commons, under date July 5, 1871, quite as appropriately expresses himself:—"I become more and more confirmed in the opinion that archæologists have been generally mistaken concerning the so-called 'Iron Age.' I am collecting further information on the subject from time to time, and as yet have met with nothing of late in opposition to the opinion above mentioned."

WORKING VERY HEAVY GUNS.

From "Engineering."

Guns are rapidly increasing in size and weight. The 35-ton gun is indeed a mere "infant," compared with some of the weapons now proposed, if not actually constructing, both at home and abroad. Unfortunately, side by side with this great increase in power, the rapidity with which these tremendous weapons can be worked by manual power alone, and consequently with which they can be fired, notably diminishes as they grow in size.

Without entering on the question of the tactics of a future action at sea, or endeavoring to fix the precise speed at which ships will engage, opinion on both sides of the Channel may be said to concur in the adoption of the "end on" mode of attack as the proper basis of all evolutions. Ships, it is said, will advance at great speed to attempt the fatal ram or torpedo attack against floating fortresses comparatively impregnable to artillery. Looking to the conditions of such a battle, and the present rate of working the heaviest guns, a French writer, Admiral Jurien de la Gravière, affirms that silence should be imposed on the guns of a ship until close alongside the enemy.

To avoid so restricted a field of action for a very considerable portion of a ship's offensive powers, the following conditions must be fulfilled:

1. Great rapidity in working the guns.
2. Large vertical arcs of training, with power of moving very quickly through them.

These two conditions are absolutely necessary in a naval combat of the future. Neither of them are satisfied at present in the English navy.

If the time during which artillery can exert its full power is so much shorter than in the days of wooden ships, owing to the very rapid movements of the ships engaged, it is evidently of the first importance that the rate at which the guns can be worked should be at least equal to that of the weapons of those days, certainly not inferior.

It is from this point of view that the recent admirable application of hydraulic power to all the movements connected with loading and running in or out very heavy guns, designed by Mr. Rendel and explained by him at a recent meeting of the Institution of Civil Engineers, is of the greatest value, and as the comparative advantages of such a system over the methods of working heavy guns actually in force at present are perhaps, as far as the details are concerned, but little known, we propose to devote a short space to their consideration. We shall also indicate a further important development in the mechanical working of heavy guns which can be brought about by the use of hydraulic power, and which completes the proposed method of working guns by this means.

First, let it be said that huge guns of this nature are now almost universally placed either in turrets or in barbette towers. In turrets, two guns are usually mounted side by side, in barbette towers one only is placed.

It is difficult to see what advantage is gained by placing two guns in a turret instead of one heavier gun. Could the two be worked as well as if fired independently, the rate of fire would certainly be increased, but it is practically impossible to load one gun in such close proximity to another monster which is being fired. Flesh and blood cannot stand the concussion, even if the danger of sparks entering the port is overlooked. It is therefore only possible to fire the guns simultaneously, and if this is the case it is probable that one heavy gun would be better than two lighter ones. The destructive effects of a shell from a 70-ton gun would be much greater than that of two from 35-ton guns, while it could penetrate a structure which would defy the lighter guns. With a single, also, there would be far more room in the turret for working the gun, while the strength of the turret itself would be greater from having only one hole in it instead of two.

Those who witness the various movements of guns mounted in turrets—as now fitted—performed independently and without reference to each other, are apt to attribute a far greater rate of speed to the firing of the gun than can be obtained when the movements are simultaneously performed in the manner in which they actually occur when fighting the gun.

Thus nothing can seem more simple and expeditious than the hand-winch gear for running the guns into the exact position for loading—an operation which has almost invariably to be performed, owing to the impossibility of adjusting the compressor to such nicety as to permit the gun to recoil exactly to the loading mark, whatever the motion of the ship—but in actual practice the case is far different. No sooner are the guns discharged than the turret is turned round to load under cover, consequently the men waiting to run in are not able to ship their winch handles until the motion has ceased, and a delay is caused by this of 1 to 1½ minutes before the gun can be sponged. If the ship should be heeling, the guns may have to be dragged up a steep incline, and a further delay is produced.

As there are no means by which the guns can be run out other than the same slow-moving hand gear, the slides of all turret guns are placed at an incline of 3 deg., in order that the guns when tripped on to the rear rollers of the carriage by hydraulic jacks may return by their own weight to the position of firing But under the condition of the ship heeling 3 deg. or more, the guns would not run out of their own accord, even when tripped on to the rear rollers, and the slow process of running the guns out by hand would have to be resorted to. With a heel of 6 deg. it is doubtful if this could be effected in less than 4 or 5 minutes. By the direct application of hydraulic power to the carriage, the guns could be run in or out under any conditions of heel or motion with perfect safety and great rapidity. The heavy and complicated machinery at present used for running in or out could thus be dispensed with, as well as the hydraulic tripping gear, for the movements of the gun being entirely under control, the carriage could run on permanent rollers or a broad smooth surface be used.

It will thus be seen that if these movements were performed with the very great rapidity and safety which hydraulic power alone can be accomplish, a much quicker fire could be sustained, inasmuch as the gun directly it was fired, and while the turret was being trained out of action, could be immediately run in and the loading commenced, while both the running in and out could be effected with equal rapidity independent of any heel or motion the ship might have, matters which at present seriously impede these movements. An effective fire from the turrets of the Devastation cannot be sustained at a greater speed than one discharged every 7 or 8 minutes, even on an ordinary practice day when the distance and bearing of the target do not materially change. With a quickly-moving target, and under the conditions of action, where rapid motion will be the chief characteristic, it will probably be found impossible to obtain more than one discharge of the turret every 10 minutes. It is true that one gun can be fired at a time, but the fire of the turret, although halved in value, is not thereby in any way expedited, as it is impossible to load one gun while the other is being fired.

The following figures show the actual time in which the loading of the guns was performed on an ordinary practice day.

The whole time of each discharge is not given, as great delay took place in the laying and firing of the guns; but to lay a gun for elevation by the pointer of the wood scale, if any accuracy is sought, takes from 30 seconds to 40 seconds, to which must be added a certain time to align the turret sights, as this alignment is entirely dependent on the motion of the ship. With the 70 or 80-ton gun this time would probably be again increased, perhaps as far as 15 minutes for each discharge.

Number.	Run in to Load after Discharge of Gun.	Sponge.	Load.		Run out and Ease Off Rollers.	Total.
			Powder.	Shot.		
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
1	1 30	1 20	1 20	3 40	0 50	8 40
2	1 30	1 30	3 25	3 20	1 30	11 15
3	1 25	1 0	0 45	2 0	1 0	6 10
4	1 30	0 30	0 50	1 10	2 50	6 50
5	1 20	0 40	1 10	1 20	2 40	7 10
6	1 15	0 50	0 50	1 10	1 0	5 5
7	1 30	1 40	1 0	1 10	1 15	6 35

But in 10 minutes of time two fleets approaching each other for a ram attack, at a combined speed of 20 knots, would pass over no less than 3⅓ sea miles, 6,700 yards, and most naval authorities are agreed that it would be worse than useless to open fire with heavy artillery at a greater distance than 1,500 yards at the very outside. It will be evident, then, that unless the rapidity in working heavy ordnance is very greatly increased, its use will be restricted to a very narrow field indeed.

In another and important particular the working of turret guns as at present fitted is defective. In order to reduce the chances of an enemy's projectiles entering the turret ports, their dimensions have been kept as small as possible. While the inconveniences of horizontal training which result from this having been met by steam rotation, it is sought to give a sufficiency of vertical training by a system of "steps," the gun being raised or lowered from one to the other by hydraulic rams.

But the probable conditions of naval warfare seems to demand not only vertical arcs far greater than those hitherto given, but also a rapidity of movement through those arcs not inferior to that obtained in horizontal training. At present there are generally three "steps," or positions, from which the gun can be fired. When on the bottom step 15 deg. of elevation can, as a rule, be given with but little if any depression; on the centre step about 8 deg. elevation, and 3 deg. to 4 deg. depression; and on the top step 6 deg. elevation and about 5 deg. depression.

In the first place the arrangement of the steps does not give sufficient prominence to a fire which it is believed will have decisive results in future, namely, a plunging fire on an enemy's decks at close quarters. Although a great height of port-sill above the load water-line is given to the latest ships, the range of depression of 5 deg. is quite inadequate in this respect. In France a depressed fire of 20 deg. to 25 deg., and even greater, is now demanded.

Secondly, the system of hydraulic lifting is altogether too slow for the rapid phases of a naval action of the future. If, for instance, in order to open fire when an adversary comes within range the guns are placed on the bottom, or even middle step, it will be impossible to make use of a plunging fire at short distances; for should the slow process of raising the gun be resorted to, it will only be with the imminent danger of finding the artillery useless at the very moment when its services are most urgently required. It is open to doubt whether such a practice is advisable or possible with the great weights with which we shall shortly have to deal. To lift the 35-ton gun from the lowest to the top step cannot be done with the existing hydraulic gear under 4½ minutes to five minutes, and 2½ minutes more are required to lower the ram out of the way. With 80-ton or 100-ton guns, this time would be considerably augmented.

A height of port to give a total vertical arc of training of 15 deg. from one position would be ample for all purposes, and would be but slightly greater than that adopted at present from which 11 deg only can be obtained. With such a height all the requirements of action would be met by keeping the gun in one permanent position for firing from which 7 deg. depression and 8 deg. elevation could be given. It is doubtful under what circumstances the extreme arc of 15 deg. elevation would be used.

Although a comparative facility has already been achieved in horizontal move-

ments of the turret and guns by the application of steam turning gear, the elevating arrangements at present in use are slow and cumbrous, and viewed by the light of the conditions of naval warfare present many serious difficulties. In all broadside guns the sight by which the gun is laid for the object is attached to the gun itself, and thus partakes of every movement of the breech. Owing to the difficulty of the problem it has not as yet been found possible to sight guns mounted in turrets, but a fixed sight is placed on the top of the turret itself and the requisite elevation due for the distance of the object is given to the gun by means of a wooden scale which is set to a certain height, and then made to correspond with other marks on the breech of the gun. The most prominent fault in this method of adjusting turret guns for elevation is that the firer has no control over the actual elevating the gun, and is, moreover, incapable of ascertaining, at the instant of firing, whether his guns are correctly laid for the object or not. A plan for directly meeting these requirements has recently been prorposed by Lieutenant H. H. Grenfell, R. N., and Mr. Edward Newman, Chief Engineer, R.N., and is now under consideration. They propose to directly connect the outside top turret sights to hydraulic elevating gear attached to the breech of the gun in such a manner that the slightest movement of the sight produces an instantaneous and corresponding movement of the breech of the gun in whatever position on the slide the gun may chance to be. The very great advantages of this plan are obvious. The captain of the turret has all the movements of the turret and guns under his entire control, and can keep his guns constantly readjusted for any motion of his own vessel or change of position on the part of the enemy, and can, moreover, discharge his guns while in the act of altering the elevation, should a favorable opportunity suddenly be presented, without danger to the elevating gear. This plan, in conjunction with the those proposed by Mr. Rendel for running in and out and loading, would place all the movements of the turret and guns under the direct control of the firer.

The disasters which arise from errors in horizontal directions are altogether insignificant when compared with those which spring from incorrectness in elevation. It may be said that if the No. 1, who, under the present system, lays the gun, is well trained and trustworthy, few errors will occur; but apart from the intricate method in use, consider the interior of a turret in action and the effect the confusion, noise, smoke, and darkness will have on the accurate adjustment of a small wooden scale on which the whole success of the discharge depends.

The experimental firing of H.M S. Captain at Vigo in 1870, furnishes an instructive lesson on this point; eleven rounds were fired as quickly as possible against a rock at a moderate distance, affording a very large target. The guns were carefully laid for the first broadside, and three out of the four projectiles hit the mark. Of the remaining seven fired in quick succession, only one shot struck this exceptionally large target.

In order to remedy these great defects and to obtain proper accuracy and rapidity in firing from very heavy guns, it is absolutely necessary:

1. That the rear sight of the turret over which the firer takes aim and directs the discharge, should rise and fall with the movement of the breech of the guns, when elevating, and thus insure their being accurately laid at the instant of firing.

2. The firer should himself be able to elevate or depress the guns so as to keep them continuously "covering" a rapidly approaching or departing object, and to fire the instant a favorable opportunity is presented.

Without such a control over the movements of the guns, the results of artillery fire will be but small. Either the fire will be delivered at haphazard, or the guns will be laid for a predetermined distance and the fire reserved until that moment. But, as often happens, the best laid plans may be disconcerted by some trivial circumstance, and smoke, a change of course, or a thousand other accidents may make the fire at that anxiously expected moment impossible. Nine out of ten men would then fire although they saw nothing to aim at. The tenth would endeavor to relay his guns and so probably lose an opportunity of firing at all. On the other hand, the captain of the turret, who has the guns entirely under his independent command by the aid of hydraulic power, calmly and continuously "covers" the approaching foe until the moment when an opportune wave exposes the bow or broadside below the armor plating,

and shot can be instantaneously lodged in a vital point.

This point has as yet received little attention. It has been thought sufficient to provide for the various movements of the gun to and from the position of firing, passing over the question of the actual laying of the gun as comparatively unimportant; yet to those who endeavor to discover what the actual effects of these ponderous weapons will be, facility in loading or running the gun in or out, whether by hand gear, water, or steam, is altogether second in importance to the question of rapid and accurate adjustment and readjustment of the gun when in position for firing. As the question is mainly connected with the technical working of the gun, it may be as well to explain in some detail what actually takes place.

Suppose two turret ships are approaching at the combined high speed of 20 knots. In one the captain of a turret has been directed to open fire at 2,000 yards. His method of preparing his guns under the present arrangements is as follows:

He fixes the turret sight at zero, and names the distance at which the fire will be delivered to the No. 1, who is inside the turret on the platform. "2,000 yards!" Nos. 1 and 2 immediately jump on to the rear part of the carriage; 1 provides the wooden scale, sets it, and holds it against the breech of the gun, 2 attends the elevating gear, and raises or lowers the breech under the direction of 1, until the pointer on the scale is against the mark on the breech of the gun, he then clamps the elevating gear; 1 returns the scale, 2 cocks the gun, and then both step off the slide, and then No. 1 calls out "Ready!" to the captain of the turret.

This process is slow and uncertain. If the turret is full of smoke, or the action be fought at dusk, the marks both on the wooden scale and on the scale on the breech of the gun are so small as to be easily mistaken. It is especially difficult in such cases to see whether the pointer on the wooden scale is opposite the correct mark on the breech, and in the noise and confusion No. 1 may easily fail to distinctly hear the distance called by the captain of the turret, and so set the scale inaccurately. It is not surprising that with so many sources of error such great inaccuracy of firing should have been obtained from the trial in 1870.

But supposing that these various duties have been correctly performed, and the guns consequently accurately laid for the distance of 2,000 yards, let us assume that just previous to reaching that distance a sudden change of course is adopted by either of the two ships, or that smoke from either ship temporarily obscures the other, or that some other of the numerous causes which may occur, prevents the captain of the turret from seeing his object, and consequently firing his guns at that instant. It will be evidently necessary to immediately relay the guns for a new distance, to do which the whole of the operation will have to be gone through over again, with several minor additions, thus:

The captain of the turret calls out the new distance, and sets his sight, the firing gear has to be locked, the tube taken out of the vent, the two numbers then mount on to the carriage, set the scale, relay the gun, reprime it, step off, and finally unlock the firing gear, when the gun is again ready for use. During the whole of this time the gun is out of action, nor is it possible for the captain of the turret to take advantage of a sudden break in the smoke or reappearance of his enemy to discharge his gun; for even if it were left primed it would be impossible to fire without destruction to the two men laying the gun.

In view of these circumstances it is perhaps not too much to say that nine out of ten men would discharge their guns, even though they saw nothing to aim at, sooner than, by embarking on the slow process of relaying, hazard the opportunity of being able to fire at all. With hydraulic elevating gear directly controlled by the captain of the turret, and a slight rising and falling with the movement of the breech, and correctly exhibiting at any moment the actual position of the axis of the gun, all this would be very different. Under these altered conditions it would not be necessary to lay the guns for any prearranged distance, inasmuch as the guns could be kept continuously "covering" the object as it approaches. The captain of the turret keeping his eye fixed along the sights, would hold the firing key in one hand, and with the other constantly adjust the elevation as the enemy gradually approached. The No. 1 placed close to him, or on the quarter platform as most convenient, would effect a corresponding change in the adjustment of the sight due to the enemy's diminishing

distance, while at the same time he keeps the horizontal training of the guns accurately aligned. It is thus seen that without intervention of a single man within the turret, the sights can be continuously readjusted for change of distance, the guns kept constantly covering the object, and discharged with certainty of striking the latter the instant a favorable opportunity is presented.

With very heavy ordnance it is unnecessary to insist on the great importance that each discharge should take effect. The time of reloading, even with mechanical appliances, is necessarily considerable, and the disaster of a lost shot would still be very serious. This power of directly controlling all the movements of the guns on the part of the captain of the turret is imperatively needed, and combined with the application of a movable turret sight would, it may be said, increase fourfold the effect of heavy artillery.

Without some such plan it is not too much to predict that lost shots, confusion, and disaster will be prominent features in the use of the tremendous artillery of the future.

THE REAL REASONS WHY CASTINGS IN IRON ARE ACCURATE COPIES OF THE MOULD.

By ROBERT MALLET, C.E. F.R.S., etc.

From "The Engineer."

The fact that cast iron does take very accurately the form of the mould in which it is cast has been for a length of time attributed to the supposed fact that the metal expands in volume while passing from the liquid to the solid state—a supposition which for more than a century has passed current, though without any sufficient proof. In a paper read before the Royal Society on the 11th of June last, an abstract of which, taken from the "Proceedings" of that society, has appeared in "The Engineer" for the 3d of July last, I have disproved by two independent experimental methods the supposed fact that cast iron does expand in consolidation from fusion. The paper itself will probably be published in full by the Royal Society in the latter part of this year. Meanwhile it may be stated that the methods pursued consisted in, first, the determination of the specific gravity of liquid cast iron, by weighing equal volumes of the liquid metal and of distilled water; the specific gravity of the same cast iron at 60 deg. Fah. being also determined; secondly, by determining the dimensions of a spherical shell of cast iron heated to bright redness, and then filled with liquid cast iron before being heated, when filled, and during the cooling back to the temperature of the atmosphere, when its dimensions were found the same as at the beginning; also by determining the specific gravities of the circumferential and central portions of the ball of cast iron when cold which had filled the shell. The central portions were found much less dense than the circumferential parts, as is well known to be the case in all castings in iron, of whatever size and form; but if the expansion in volume had taken place in the ball cooling by radiation, the central portions must have been found much more dense than the circumferential parts. The agreement of these two independent trains of experiment removes all doubt as to the completeness of the proof that cast iron does not expand in volume in passing from the state of liquid fusion to that of solidity by cooling; and it is therefore certain that the degree of exactness with which cast iron takes the form of the mould into which it is cast is to be otherwise accounted for. It is not necessary I should here advert to the objects in relation to certain lunar volcanic theories with which the above experiments were undertaken, nor to the conditions under which cast iron in the solid state may or may not float on cast iron in fusion; the latter facts, erroneously interpreted, having been, in fact, the foundation upon which the supposed notion of the expansion of cast iron during consolidation has been based. For these and the details of the experiments I must refer to the paper itself. In the mean time some useful deductions of a practical character may be drawn from the facts ascertained. Were it the fact that cast iron in solidifying did expand in volume, a little consideration will show that such expansion would result, not in the casting being an accurate copy of the mould

—whether of green or dry sand, or loam—but must be a distorted copy, the expansion in volume of the metal filling the mould being, in effect, the same as if it were exposed to the hydrostatic pressure of a liquid pumped into it, the yielding to which would be greatest where the walls were least resistant, or where the force to which they are exposed is greatest—namely, where the surface exposed to pressure was the largest. Thus, for example, a flat plate mould from a pattern of equal thickness throughout would when cast be no longer of equal thickness throughout, but have one or both of its broad surfaces forced outwards so as to make the plate thickest towards the central parts, while the edges and corners of the plate which consolidate first would remain nearly unaltered and the metal be found not even completely forced into contact with those parts of the mould; in fact, no form of casting except that of a sphere could under the supposed conditions of expansion in volume remain an undistorted ectype of the pattern, nor could any rigidity in the mould prevent this, the expansive force being by hypothesis irresistible, like that of water freezing into ice.

Cast iron does, however, as is well known, take the form of the mould, as formed of sand or loam by the usual methods of the founders, with great fidelity. We must except, however, the case of chills or massive moulds of cast iron, the liquid metal cast into which is so instantly chilled by contact as not to form a very accurate transcript of the mould. But though cast iron does take a very sharp and accurate transcript of the mould when cast, it does not do so to a greater extent than do several metals to which the supposed property of expanding or consolidation has never been attributed. Thus zinc affords castings of exquisite sharpness from sand moulds, as all those must have remarked who have seen the superb ornamental castings in that metal for architectural and other purposes, which form the staple trade of the great German and Belgian zinc foundries. Lead, also, when carefully preserved, while in fusion, free from oxidation, and cast in slightly-greased moulds so as to reduce any oxide formed therein, affords castings of exquisite sharpness, as may be observed in those of the ancient lead work of the roofs of churches and other buildings of from 200 to 300 years ago in France and Belgium. Gold, silver, copper, and most of their alloys, on the contrary, afford generally more defective castings, and wanting in sharpness. The circumstances upon which these opposite results arise are extremely complicated, and to fully elucidate them would require more space than can be here afforded; they involve conditions mechanical, chemical, and molecular, affecting both the metal cast and the nature of the mould in which it is cast, as well as the relations of these to each other. Among these the following are, perhaps, the most important: First, the density of the metal itself. Whatever be the nature of the metal, it fills the mould when full under a certain hydrostatic pressure due to the height of the liquid column and to the density of the metal, and whatever the metal may be, this is the mechanical force by which it is compelled to follow and fill while liquid the sinuosities of the mould. Let us suppose the liquid head constant, say 2½ ft. or 30 in., we readily see how enormous a difference there yet is in the mould-filling force due to density alone in the five metals, aluminum (which gives extremely defective castings), zinc, cast iron, lead, and gold, their densities being,

	Specific gravity.	lbs. per sq. in. under 30 in. head.
Aluminium	2 560	2.82
Cast iron	7.110	7.856
Zinc	7.146	7 896
Lead	11.360	12 552
Gold	19 340	21.371

Thus, in the last of these metals the hydrostatic pressure tending to fill the mould completely is about seven and a half times greater than in the case of aluminum, and yet both these metals produce inferior castings, while the three intermediate metals afford sharp and good ones. Secondly, the specific capilarity when in fusion and viscosity while passing from the liquid to the solid state. Different metals are liquid in very different degrees while in perfect fusion, and therefore require very different degrees of pressure to force them into angular cavities. Upon this point physicists have as yet given us but little exact information. The greatest diameter of spherical drops capable of being assumed by any metal when taken in connection with its density is, however, a rough measure of the resistance which each presents to being forced into angular cavities of a mould of such material that it is not wetted by the liquid metal; thus fluid solder will readily penetrate between the edges of two clean

tin plates, but will not enter at all if the plates be tarnished or blackened by a candle flame. Drops of mercury cohere at larger diameters than those of liquid lead. So also different metals differ in the range of viscosity through which they pass between their state of most perfect liquidity and that of solidity. Lead and some of its alloys, such as plumbers' solder, pass through a very long range of viscosity; brass and copper do so likewise, though in less degree; cast iron and in general all the metals that crystallize most readily and best, pass through a very brief stage of viscosity. Where the melting point of the metal is a low one, one of the effects of this prolonged viscous stage, during which the metal contracts by loss of heat, is that its withdrawal from the sides of the mould is not compensated by a sufficient continuance of hydrostatic pressure, owing to imperfect liquidity. Cast iron is remarkably free from this objection; its melting point being very high and its range of viscosity small, and confined to a small range of temperature, the metal is maintained, though constantly contracting by loss of temperature, in close contact with the mould by hydrostatic pressure up to within a brief period of its setting. Thirdly, upon the tendency of the metal to oxidate or combine with other elements presented to it in casting, and producing compounds less fusible than the metal itself, greatly depends the perfection or imperfection of the castings produced from it. Fluid zinc oxidates but very slowly up to a temperature somewhat above its melting point, but it oxidates rapidly at and above a bright red heat; hence zinc gives perfect castings; but when it is alloyed with copper, the melting point of the brass is raised to such a point that the zinc oxidates very rapidly, and produces that "tailing" and general scurfiness of surface which is the plague of the brass founder, and the oxide of zinc is not reducible back to metal at the temperature at which brass is cast by any chemical agent capable of being introduced into the substance of the mould. In cast iron, on the other hand, its tendency to oxidate by contact with the atmosphere when in fusion is opposed by the presence of silicon and carbon in the metal itself, and any oxide superficially formed is reduced back to metal with great facility by the hydrogen and carbonic oxide evolved from the moisture and charcoal, or coal dust, or other carbonaceous matter entering into the constituents of the mould. Gold is inoxidizable, but possesses a vigorous affinity for sulphur, and it is probable that the film which may be observed upon the surface of molten gold in casting, and which produces "tailiness" in the ingot or bar, consists of some sulphur compound taken up from the gases from the fuel employed for fusing it. Copper also casts badly, as when in fusion it is constantly either taking up carbon or oxygen as the heat of the furnace is either a reducing or an oxidating one, and the great cleanness of castings produced from phosphorized copper arises from the presence of the small amount of that element precluding it from taking up carbon, on the one hand, and shielding it from oxidation on the other. Fourthly, a high melting point and a high specific heat are favorable to the production of perfect castings, as prolonging the time during which *cæteris paribus* the metal filling the mould is subjected to its own hydrostatic pressure, thus more completely forcing it into sinuosities and expelling air bubbles or other gaseous matters. If the fusing point be very low, as in the case of lead or tin, the viscous point is so rapidly reached by the loss to the mould of the small amount of heat present in the metal that there is but little chance of air bubbles or particles of unreduced oxide being previously forced out. Fifth, the absolute amount of contraction of any metal between the temperature at which it is poured and that of the atmosphere, forms also an element in the perfect correspondence of the casting to the form of the mould in which it was cast. On comparing this rough sketch of some of the principal conditions upon which the degree of perfection of castings in various metals depends, it will be obvious that among all the metals commonly used for castings in the arts, cast iron occupies an extremely favorable position; its density is sufficient to press it when liquid effectively into the mould, its capillarity is not very great, its range of viscosity is small, and it possesses the paramount advantage that whatever oxide may be formed in the casting processes is precluded from becoming diffused throughout the mass by the silicon and carbon present, and that any oxide formed on the surfaces in contact with the mould is instantly again reduced by the hydrogen and carbonic oxide evolved from the mould itself.

In these conditions, indeed, cast iron

may be said to stand unrivalled among metals in the perfection of the castings made from it, and they are quite sufficient to account for that perfection without calling in the now disproved supposition that it expands like ice at the moment of consolidation. The experimental determination of the specific gravity of liquid cast iron adverted to at the beginning of this paper affords us the means—and for the first time—of determining the total dilatation in volume as well as the linear dilatation of cast iron of the quality experimented upon, viz, the fine-grained, bright gray tough cast iron employed by the mechanical engineers. As the specific gravities of this iron when cold and when melted were 7.170 and 6.650, so that the unit in volume when cold being taken as 1000, was increased to 1078.2 at the temperature somewhat above the melting point at which the iron was poured; the total dilatation in volume being thus 0.0782, and this divided by three—*i.e.*, neglecting all but the first term of the series—gives for the total linear dilatation 0.02606, which, taking the whole range of temperature between 60 deg. and 2,400 deg., and if we assume the dilatation uniform throughout the range, gives a coefficient of dilatation of 0.0000.1086 for 1 deg. Fah. This, however, it is not quite correct, as the rate of dilatation increases rapidly within a few degrees of the melting point. The dilatation found as above is also in excess of that due to the precise range between 60 deg. and the melting point of cast iron, the higher temperature in my experiment being somewhat above the melting point, exceeding it by probably about 200 deg. Fah. My direct object being simply to prove that melted cast iron is not denser—as has been stated—than the same cast iron in the solid state, and not that of ascertaining the exact dilatation due to the precise range between 60 deg. Fah. and the melting point; we are enabled, however, incidentally to deduce the latter with approximate accuracy. I must reserve however, for a future communication some further remarks upon this part of the subject, as also upon the interesting phenomena of the movements observable in large masses of liquid iron, as in the largest crane ladles, which have been erroneously appealed to as affording proof that liquid cast iron is denser as its temperature is higher.

AMERICAN ROLLING MILLS.*

From "Engineering."

The object of this paper is to describe the general arrangement of American steel rail mills of recent type, and some of the more important details of their machinery and practice rather than to bring forward any remarkable novelty. The character of mill structures in the Northern States is largely affected by meteorological conditions. A series of small-span roofs covering a continuous area is impracticable; heavy snows would drift into the valleys, and by alternate freezing and thawing, fill them with a dangerous weight of ice. There may be transepts with diagonal valleys and lean-to roofs like those of aisles, but the succession of slopes should be uninterrupted from ridge to eaves. These conditions require trusses of long span, but not necessarily of greater cost, as intermediate columns and their foundations are avoided. The absence of columns also facilitates the arrangement of machinery. The extreme variations in temperature require a mere shed in summer, and a close building in winter. These conditions are best met by setting the roof on piers, rather than on a continuous wall. The openings are stopped above by windows, and below by doors or by light panels, removable in summer. For ventilation, a number of light chimneys or lanterns of large diameter are found better and far cheaper than a continuous lantern-roof. The mill shown in the diagram on the wall is part of the Edgar Thomson Steel Works near Pittsburg, now nearly completed. It consists of iron trusses, 20 ft. apart, covered with sheet iron, and standing on iron columns 25 ft. high. The main building is 100 ft. by 380 ft., and will be lengthened 80 ft. to accommodate four more re-heating furnaces. This mill is specially arranged to bloom 2-rail or 3-rail ingots, and to roll these blooms into rails, at the rate of 200 tons per day. It is also adapted to rolling heavy merchant steel up to 60 ft.

* A paper read by Mr. A. S. Holley, of Brooklyn, N. Y., before the Iron and Steel Institute at Barrow, England.

lengths. The 23-in. 3-high rail train is divided into three instead of two stands of rolls, in order to be strong enough for heavy sections. The additional lateral movement of the rail on the hooks thus made necessary causes no delay in the long run. Space is left at the end of the train for two stands of merchant roughing and finishing rolls, which may obviously be changed as often as required, without interrupting the continuous working of the rail train. This arrangement renders it practicable to fill small orders for exceptional patterns of rails, and for high-priced merchant work, by executing them in connection with rails, at about the cost of standard rails. By means of a movable saw-carriage the same driving apparatus which draws the rail to the saws also places the carriage in position to receive the bar from either stand of finishing rolls. Two of the carrying rollers behind the train are driven from the saw-engine, and deliver the rail upon the saw-carriage. The rail is usually drawn upon the hot straightening plate by power, thus employing the minimum of labor. It will be observed, that while both in front and in rear of the finishing rolls there is room to handle pieces 60 ft. or more in length, the floor space is otherwise occupied around the roughing rolls, where shorter pieces are handled; and generally that no floor space is wasted, while there is ample room for all the operations. The space between the furnaces and the hot-bed is no greater than would be required for 30 ft. rails. Ordinary lengths are cut by double saws for fast working; 60-ft. lengths are cut, one end at a time, by a swinging saw, in order to avoid moving the bar laterally, which would require a saw-carriage 60 ft. long, and the same additional length of building. The 30-in. 3-high blooming train is so placed as to occupy room in the body of the mill otherwise not used, and is so set with reference to the 3-ton hammer, that the blooms are cut in three and chipped, on their way to their reheating furnaces. The hot straightening plate is placed between two hot-beds, instead of at the end of one, in order to better accommodate two cold straightening presses. As there is not sufficient room across a mill otherwise wide enough, for a hot-bed on which 200 tons of rails per day can be conveniently handled, the necessary addition is made, and at the same time a 60-ft. hot-bed and straightening plate are provided for long lengths, simply by placing two 30-ft. plates and their hot-beds end to end. The finishing machinery is arranged chiefly with reference to economy of labor in moving the rails, but also with regard to economy of room, as it must all be under roof. The rails pass but a few feet from the hot-beds to the cold straightening presses, and thence by an equally short route to the cold beds. The punching machines and drilling machines are so arranged that they can all work at a time on either long or short bars, and can thus finish all the product of the trains. The rails lie always longitudinally with the building, and pass straight out at its end, the only lateral movement being across one of the short hot-beds and cold-beds. The finishing tools are in this case driven by a single engine and overhead shafting, although attaching a small engine to each press and punch is a more common practice. Changing rolls is done by means of a portable crane, which ordinarily stands behind the pinions out of the way. Fixed cranes are commonly used for this purpose, and in some heavy beam and merchant mills, where numerous changes are required, hydraulic cranes, like those in Bessemer works, have been adopted. Placing the reheating furnaces across the building in two rows, as shown, occupies less floor space and is more convenient, considering distance from the rolls, and the working of the double ingot furnaces, than placing them parallel with the building.

The arrangement once so common of furnaces along one side of the building and trains end to end in the middle, both lying lengthwise, is in the newer mills replaced by the arrangement here shown, viz.: trains lying transversely—furnaces at one end, and finishing tools at the other; and it is indispensable for conveniently working long bars. Gas reheating furnaces are exclusively employed in this mill, and in the last two steel mills started in America, as well as in several new iron rail and merchant mills; gas furnaces are being gradually introduced in the best old mills, and it is probable that few American works, save those erected under very exceptional conditions, will in the future embody the old and wasteful system of burning solid fuel in individual furnaces. The Siemens system is of course the most common, being the most highly developed, and it is, without exception, as far as the author is aware, working well, with anthracite culm, and with

every variety of bituminous and semi-bituminous coals.

The Frank system of continuous regeneration, as improved by Mr. Blair, in his open-hearth steel manufacture at Pittsburg, and the Ponsard system, as improved by the Messrs. Sellars, in their puddling and reheating furnaces at Edgemore, are likely to be extensively introduced. For re-heating ingots, a double flat-bottomed furnace is employed, because it is more economical, both as regards construction and floor-space, than two single furnaces of equal capacity, and because ingots, especially when charged hot from the moulds, do not require a heat which produces a troublesome amount of cinder. The bloom furnaces, however, are made single, because they require a sloping bottom and a slag tap in the rear; but chiefly because it is impracticable to secure the uniform high heats necessary, while constantly charging into and drawing from a large double furnace. The ingot furnaces are 20 ft. by 11½ ft. on the working bed; the bloom furnaces are 20 ft. by 6¾ ft. The ingot charging and drawing apparatus involves the minimum of labor and of cost. A charge of 14 in. ingots, weighing about a ton each, is laid, in the adjacent Bessemer works, upon a railway car. When the ingots are crystallized, but still red hot, the car is drawn to the reheating furnace by a small locomotive. A workman then thrusts a long peel, made of gas pipe, through a notch in the car, under the ingot, until a stop on the peel comes against the rear of the ingot; he then passes a chain fixed to a hydraulic piston, around a sheave which lies on a beam in front of the furnace, and slips it over a V in the end of the peel. Water then being admitted to the hydraulic piston, the peel slides smoothly into the furnace, carrying the ingot with it; turning the peel to one side, by means of its handles, rolls the ingot off. Thus, in four or five minutes, two men and a boy can charge a Bessemer heat of hot ingots. The drawing is done by throwing a hook over the ingot, and passing the chain the other way around the sheave. The ingot slides out upon a hand-bogie, which is readily guided by one man, down a slightly inclined floor to the blooming mill. Here the power feeding-tables, patented by Mr. Geo. Fritz, pull it off the bogie and pass it alternately backwards and forwards through the mill, turning it over as required. Two men and a boy, by means of these tables, roll an ingot weighing a ton, from 14 in. square down to 7 in. square, by sixteen or eighteen passes, in from 3½ to 4 minutes. The most improved features of American roll-trains, for both heavy and light work, are illustrated by the wall diagrams of a 14½ in. bar train, constructed by Mr. John Fritz, at the Bethlehem Iron Works. First, like all American 3-high mills, it has grooved top and bottom rolls, instead of grooved bottom and middle rolls, thus greatly economizing in length of rolls, and preventing the necessity of turning the bar over after each pass. The grooves open alternately upward and downward, and hence the fin that was formed in the top of the groove, on the lower pass is smoothed down by the solid bottom of the groove on the upper pass. Secondly, the grooves are opened and closed while the rolls are running. This may be done by hand, as required, or rapidly after each pass, by the power of the engine. In this way, the bar may be worked over and over in the same grooves, instead of requiring a separate groove for each pass. Rectangular bars, and many such shapes as beams and angles, are thus worked, in many of their passes, in the same time as by fixed rolls, and with much less total length of rolls than is required by the ordinary 3-high or 2-high mills. This is especially convenient for odd sizes. The bolsters of the middle roll are fixed solidly upon shoulders in the housings by bolts in the heavy mills, and by struts (to facilitate changing rolls) in the lighter mills. The top and bottom rolls are simultaneously raised or lowered by the four housing screws, and these are all revolved together, by means of the vertical shaft, the horizontal shaft that connects them and the horizontal hand-wheel shaft and the attached gearing. The upper counter-shaft, which is continuously driven from the mill engine, is made to turn the hand-wheel shaft (which is constantly coupled to the screws) in either direction, by means of belts and a friction clutch. Thus the four screws may be simultaneously revolved either way, and the grooves opened or closed either by the friction clutch or by the hand-wheel. The rolls are counterbalanced so as to reduce the wear on the screws to the minimum, and in such a manner that the whole apparatus hangs conveniently in the pit between the foundations. The housing screws

are fitted with telescopic sheaths, so as to prevent the entrance of dirt, and are oiled by means of a central vertical oil-hole and radial holes leading from it to the exterior of the screw at various points. Housings with solid tops being stronger and more durable than those with movable caps, roll changing is facilitated by making the solid housings so high that when the distance-piece under the screw and the middle roll struts are removed, the bolsters of the top roll can be raised enough to permit the roll to be lifted and swung out. The other rolls are then removed in like manner. Driven feed-rollers are employed both in front and in rear of the rolls, in all mills for heavy work. The first blooming train, in which the rolls were adjusted by power derived from the engine, was erected by the author, at Troy, in 1870, and has been almost constantly running on 12in. and 14in. ingots. In this mill, the middle roll is shifted after each pass, the top and bottom rolls being fixed. The blooming trains at the Cambria and the Bethlehem works, also all the new rail and merchant trains at Bethlehem, and the trains in the Phœnix Iron Company's new mill, and in the Otis Iron and Steel Works, are so constructed; and these features seem likely to be embodied in first-class mills generally in America. In the more recent American mills, roll trains are machine-fitted on all their bearing surface (excepting only the couplings) like steam-engine work, and with the same accuracy; and this, to a great extent, accounts for their large and constant production. The working details of rail mills of this kind are as follows:—Ingot heating is not divided into "rounds;" ingots are charged a Bessemer heat at a time, hot from the moulds, into whichever part of a furnace has most room for them, and the hottest ingots are drawn as fast as required for rolling. There may sometimes be 30 or 40 ingots in the two furnaces at a time. Blooming trains are ordinarily worked up to the capacity of a pair of 5-ton vessels, averaging 150 tons per 24 hours; the Cambria train with two such furnaces has heated and rolled 2-rail ingots at the rate of 300 tons per day. The output, with 3-rail ingots, is about one-fourth greater. The time of rolling a 14in. ingot to a 7in. bloom in sixteen to eighteen passes is from 3½ to 4 minutes. The speed of the train is from forty to forty-five revolutions per minute. The engine, directly connected, is 36in. by 4ft. or its equivalent, carrying steam at 70 lb., and having a 40-ton fly-wheel. The blooms are cut while red-hot into three single rail blooms, either by a heavy shears or under a 3-ton hammer. Chipping, when it is required, is so thoroughly done hot under this hammer that no cold chipping is required. Blooms are often taken hot to the reheating furnaces, but this practice is not as yet general. As most American works have but one pair of 5-ton converters each, and make but 150 tons per day, the rail mills are kept full by rolling steel rails for two or three weeks, and then iron rails for one or two weeks. The regular capacity of the average American 3-high train may be put down at 200 tons per 24 hours; of 60 lb. to 65 lb. rails 30ft. long, although most of the mills have too few re-heating furnaces for so large a product. The Scranton Mill for some time averaged 440 iron rails in one turn, out of eleven ordinary re-heating furnaces, or at the rate of some 225 tons per day. The Superior Mill at Pittsburgh, and the Danville Mill have averaged 360 iron rails per turnout of ten and twelve furnaces respectively. The Cambria Mill and the Troy Mill have frequently made 330 to 340 steel rails per turnout of nine furnaces, which is 180 to 190 tons per day, or from 1,000 to 1,040 tons per week of eleven turns, or five and a half days. A 6½in. to 7in. bloom is rolled into a 60lb. to 65lb. rail in thirteen to fifteen passes; the rolling occupies 1½ to 1¾ minutes. The speed of 21in. to 24in. trains is from seventy to eighty revolutions per minute. The engine—direct—is, for steel, the equivalent of 46in. to 4ft., carrying steam at 70lb., and having a 56-ton fly-wheel. The fuel employed in gas furnaces does not exceed 400 lb. per ton of product for each reheat; the steam coal varies greatly with the character of engines, and averages some 600lb. per ton of rails for all rolling mill purposes. The greatest economy of the gas furnace lies in its saving of oxidation. Careful experiments at the Union Iron Works, Pittsburg, show its saving to be 5 per cent in heating iron beam piles, as compared with the coal furnace. A year's practice at the Washburn and Moen Manufacturing Company's Works at Worcester, gave $2\frac{83}{100}$ per cent. waste on 1¼in. iron wire billets, against an average of 7 per cent. with the coal furnace; and at the same works a week's run has been made with $1\frac{34}{100}$ per cent. oxidation. The saving of steel is, of course, less than that of iron, because the

temperatures are lower. The future improvements most required would appear to be labor-saving machines to handle the work at the rail rolls. A better rail straightening machine is also very much needed. The limit of production for a single train seems to have been practically reached at 200 tons, or over four miles of bars per day; improved quality and machine-handling are now the problems that first require solution.

In the discussion which followed,

Mr. Edward Williams said there was nothing like the amount of work said to be done in America had yet been done in this country. He did not see why the quantities mentioned by Mr. Holley should not be produced; and he thought what had been done on one side of the Atlantic would probably be done on the other. He should like to ask Mr. Holley whether it had ever occurred to steel rail makers in America to roll rails in the form of a tire, and so save crops. It seemed to him that this was possible, and that it would not be difficult to get such exactness in the weight of the moulds as to bring the circle almost exactly to the size required. To get an open circle and straighten out the rail afterwards would be a simple operation; and he had thought for a long time that in this direction there is a possible economy of a very important kind. It was said that there was a continual stream of ingots going into the reheating furnace, and that they were not charged in rounds, as the custom was in this country; but he presumed that this only applied to first heating, and not to re-heating. He thought that to keep a constant stream of ingots going into the furnace, and another stream running out, if they only wanted heat enough for a bloom or hammering ingots might do well enough, but they could not adopt that system with reheating furnaces where they had to get ingots up to a rolling heat. Mr. Holley told them that the future improvements most required were not labor-saving machines, but the work of rolling rails. He was not unmindful of the cost of the operations as now carried on, and he believed it was quite possible to economize very much; but at the same time he thought there was an economy—a more pressing kind than either of these—namely, the economy that would result from dealing with the fluid pig as it came from the blast furnace, instead of casting it into pigs and carrying it through the needlessly costly and tedious process of remelting. He had been forced into the consideration of this matter by the necessities of the steel works they had at Manchester, where they had been making a good deal of steel at no profit at all for a long time back. With a view to reversing the state of things, he had been going into the elements of cost in the hope of getting rid of some of them, and he found that the cost of bringing back again into fluid form the stream of metal that was originally fluid in the blast furnace was something tremendous Given any particular day, and there might be seen at the furnaces at Witton Park little streams of fluid pig iron running down a channel into pig beds. A week afterwards the same metal is fluid again, and running down a little sand trough, no better, but rather worse, and less in quantity than it was originally, while 20s. per ton or more has been expended needlessly on the metal between the times. He had come to the conclusion that this of itself is a sufficient reason why the manufacture of steel rails in the neighborhood of Manchester, or anywhere else where there is a large carriage to pay, was not so profitable as it ought to be, and that with very simple appliances and some little attention, it would be quite possible to get the iron from the blast furnances taken at once to the converters and turned out in the shape of Bessemer steel ingots. The coke and ore put into the blast furnace to-day should be steel rails to-morrow, thus effecting a great economy without any counterbalancing objection that he could see; and he was of opinion that this system would very shortly have to come into operation. In point of fact his own company—Bolckow, Vaughan & Co.—had decided to make the attempt, and before long they would either have the thing in successful operation or they should have failed; but he hoped the former. He should like if Mr. Holley would kindly say what had been done in America in the way of blooming steel ingots in four rolls. They had been using at Manchester blooming rolls on the system established by Mr. Chas. Wild, and they were working successfully. He thought that all the advantages and all the reasons educed from their experience were in favor of treating iron in that way; and he thought there was no valid reason why a sufficient num-

ber of rolls, the one before the other, should not be set down, so that the steel ingot might be converted into a bloom by passing from one end to the other, and thus avoid all the trouble they now had with working carriages, reversing, and all that sort of thing. The cost of a blooming machine would not be great, and the rolls would be small short strong things, and not very expensive. Mr. Holley pointed out that by the system adopted in American rolling mills by lowering the rolls they might work a pair in the same groove several times without changing the rolls. That could not, however, apply to a flange rail, or any rail requiring side work; it could only be by passing from one groove into the other. The rolls might be brought together or taken apart very easily, no doubt; but how any work could be put upon the flanges of, say a quarter rail, he failed to see. They might have some mode of doing it not generally known in this country, and he was sure they would be glad if Mr. Holley would explain it to them. He rather envied the mill that could make 1060 tons of rails per week. They had never yet come up to that; but probably they would get a little more energetic, and come up to it by and by.

Sir James Ramsden said that the proposal to run fluid iron into the Bessemer converter from the blast furnace had been under the consideration of the Barrow Company for some time. They tried some experiments in this direction, and came to the conclusion that they were very doubtful, and that they could not produce the same quality of steel, or the quality necessary to satisfy the market at the time. In making the best quality of steel rails, gentlemen will be aware that it is necessary to have certain mixtures of iron; and the iron they run to day as pig iron, if used in the converter tomorrow, would not make the same quality of steel as if it lay for three or four weeks in the pig yard. With reference to the rolling of rails in a circular form and then sawing them through so as to save the waste of crop ends, the Barrow company had also the question under their consideration and decided it to a certian extent. They did now roll hoops of a certain diameter, and there was a large hoop being rolled at the mill on the previous day intended to be used for a certain purpose; but they had come to the conclusion that the best mode of reducing waste was that of rolling long lengths, and they now rolled three rails for two crop ends. The same subject had engaged the attention of Sir Joseph Whitworth, who proposed to make plates by rolling them in large pieces, and then sawing them through. They should be glad if Mr. Williams could show them that he can use the fluid pig iron directly in the Bessemer converter. There would be an enormous saving in the direct process, not only so far as the process itself was concerned, but also in several matters of detail and in the cost of plant.

Mr. Schneider said with reference to the idea proposed by Mr. Williams, that there was one most fatal objection to it, and that was that it was utterly impossible, while the pig iron was in the furnace, to know what its quality was. The whole reputation of the Barrow Steel Works was based on the uniform quality of the steel which they produced. They have had the whole of one cast from the same quality of pig iron; and if they were to run the molten metal direct from the furnace into the converter, they should have accidents with steel rails in the same way as they had with iron rails. The real secret of making good steel lay in this, they must have a pile of pigs brought out cast by cast, placed in a long row and showing uniformity of quality by having every single pig tested before it was put into that row, by breaking it, and seeing what its quality really was, then by taking a uniform depth of pigs along the whole length of 100 yards, so that they had the same quality all through the average of a week, as nearly as it was possible to get it, until they reached the end of the pile. There was a certain amount of sand clinging to the pig which the action of the atmosphere removed, but they could not otherwise describe how it was possible to get better results from pigs exposed to the atmosphere. But the real point to which he wished to direct their attention was this, that they could not secure uniformity unless they cast the iron in the form of pigs and then distributed it, so as to get thousands of tons of the same uniform quality. By this means they could secure uniform results, and defy all the railway inspectors in the world.

Mr. Williams said that Mr. Schneider's was a good old orthodox faith, having only this blemish, that it was not true. It was the old faith which they all held and implicitly believed in, but a good many of them, himself among the number, had been

giving it up bit by bit, until as a matter of fact, it was now pretty well nigh all gone. First of all as to this question of quality, there was no simpler method of maintaining quality than that of using a mixture. If a man making steel would but come to the resolution that he would make it of, say ten or a dozen different qualities of iron, that should all be the best of their sort, and bought subject to being the best of their sort, it was clear that he need take no more trouble for himself, and need waste no discussion upon it. It cannot go wrong. This mixture system would stand in the place of management, and if they laid down as a rule that Bessemer works or foundries were to be managed upon this happy-go-lucky principle, of course the best system was that of mixtures. But it was possible to work with only one kind of iron, which must, however, be the right one, and the man dealing with it must know that it is the right one, and must take care that he is using and making the right kind of material. There was no difficulty in knowing what the iron was before it came out of the furnace. You knew as well what it was when running out, as you knew how many fingers were on their hands. He had been for three years making steel from one kind of iron from one furnace, without any difficulty; and not one out of every thousand tons of pig was so doubtful that they did not let it go into the converter like the rest; and they believed that at Gorton they made the best steel in England; at any rate they found no difficulty. They had inspectors and other gentlemen of the most particular kind going on testing and testing until further testing was absurd, and their rails were beyond all question as good as could be wished. That they would never have an unfortunate rail that might break, it would be absurd to say, for it would be impossible to prevent that by any expenditure. That, however, was not the average rail. The worst rail was the one that did not come to pieces in course of rolling, but which, if it had been a degree worse, could not have held together; this was the rail that gave the trouble; and no amount of money they could spend could do any more than reduce the number of such accidental incorrigibles He believed it was a real fact that iron did get better by being in stock. He did not know how it was, but he found that iron as a rule not very good if put into stock for some time was less bad when it came out again. This was a matter that some chemists ought to be able to explain, but which he was not. With regard to the subject of crop ends, a great economy had been effected; and it was no doubt a great advantage in that direction to have two crop ends only to three rails; but if the tire system would answer, they would have no crops at all; and if there was no counterbalancing disadvantage, it would be better even than the excellent system of rolling they had seen that day at Barrow Works.

Mr. W. Richards, of Ebbw Vale, said that the making of ingots from the blast furnace direct had gone far beyond the region of experiment. In the south of France it was being done regularly, and they had also done it at Ebbw Vale. They had two blast furnaces built opposite their Bessemer works, and they got two tons of fluid iron out of one furnace, and 2½ tons from the other, and carried it direct to the Bessemer converter. The iron they got was so uniform that there was not the slightest difficulty in making ingots of a fine quality. The steel turned out of these works was well known and bore a high character for excellence of quality. The process was started about three years ago, and was being worked continuously day and night. At the Seraing Works, in Belgium, they were so satisfied that this could be done, that they were putting up a plant in front of their furnaces, and they are sure of successful results. He thought a great deal of credit was due to the American gentlemen for the immense turnout of ingots they showed. They turned out 125 tons per day—he supposed of twenty-four hours—from a pair of five-ton converters. He did not think that in England they were doing anything like this; but they came nearer to America in the rolling of rails than in the making of ingots. With one pair of engines they turned out at his works a thousand tons of ingots and rolled them into rails in one week.

Mr. Thomas Claridge remarked that at the Chillington Works in South Staffordshire, running iron out of the blast furnace direct had been done for more than twenty years.

Mr. Snelus said there could be no difficulty in running iron direct from the blast furnace to the converter. The thing was to ascertain the reasons why this process had failed before, or the conditions necessary to make it successful. If the blast

furnace was working with a gray cinder, the iron would run out gray; if they put in a good cinder they would have iron free from sulphur; but that iron might come out with 2 per cent. of silica, or only 1 per cent., and on the other hand it might come out with 5 per cent. of silica. Those of them who were accustomed to the Bessemer process knew that if the silica was below 2½ per cent. they got a skull. If it was as much as 5 per cent., it would blow so hot that the bottom would come to grief in one or two heats. They must therefore insure regularity in the silica, if they would get their furnace to work properly. If there was a black cinder in the furnace the iron was not likely to be suitable for the Bessemer process under any circumstances; but if there was a good gray cinder they might take it for granted that the iron would make good steel. What they wanted to do was to equalize the silica in the metal if they found that it was free from sulphur. He had advocated this plan for a long time, but it had been ridiculed, and they were rather conservative in his part of the world. He saw no difficulty in taking two blast furnaces, and not only running the iron into the converters direct, but also insuring regularity in the mixture. Most chemists could tell how much silica there was. If the iron coming out of the two blast furnaces should by any accident be too silicious it could be toned down; but the first essential was to get the metal sufficiently silicious; and to do that it should be run into a separate vessel as in America, and then run into a ladle, which is balanced, from which 1200 lbs. of steel can be run into the converter. If they had an intermediate vessel between the blast furnace and the converter, and found the amount of silica in the iron before it was used, they would have no difficulty in keeping it regulated, and they would find it easy to keep it right in the blast furnace. If they could ensure 2½ per cent of silica in the metal, the metal would be better and not worse, for being run direct from the blast furnace. They would get a better rail by working at a low percentage of silica; but they would be liable to get a skull, and the silica remaining behind would make a brittle rail. They started, of course, from the beginning, and assumed that the metal contained no phosphorus. With respect to the improvement of the pig iron by standing, he did not think there was any doubt that it was due to the removal of the sand, and it would be more evident even in the puddling furnace than in the converter, because it ran away with the fettling, prevents it from being as effectual as it should be, and so wastes the metal.

Mr. Josiah T. Smith said they were now discussing what they might as well leave alone, because they would have all the facts before them in a very short time at the Gorton Works; they were going to remove the Bessemer plant to beside the blast furnaces, and it would be better then to hear the result than to speculate upon it now. He saw no reason whatever why the Bessemer process should not be conducted successfully by running the iron direct from the blast furnace to the converters, provided they were careful in the selection of their ores, and exercised due care in the filling and working of the furnace; but he was bound to say that at the present time he did not see how that care was to be obtained. Given that they had the care and the proper material in the furnace, it was quite clear to his mind that no improvement took place in the actual remelting of the pig in the cupola; in fact, he should rather say the reverse. But with their present practice they knew that they had irregularities, and that they did not always use the same class of ores; and it was impossible, he thought, to sufficiently distinguish those classes to make an absolutely regular mixture. Their practice at Barrow was to have long lines of broken pig iron, so arranged that in no one cast in the converter did they use more than 3 cwt. to 4 cwt. of any particular cast from any particular blast furnace in the same day. They would be exceedingly glad if his friend, Mr. Williams, would help them out of this difficulty. If they were able to do it at Manchester they would no doubt be able to do it at Barrow. But he did not see how they should be able to do it unless they had a marvellous improvement in both their workmen and themselves, or unless they imported some talent from Middlesbrough. It struck him, from the observations made by Mr. Williams, that he must have had considerable experience of bad steel. In the early days of the Barrow Works they had those difficulties to deal with, but they did not see them now, simply because they adopted this peculiar method of mixing the

pig iron before putting it into the converter. He had heard Mr. Holley's paper with great interest, and it made him somewhat ashamed of the production they obtained in their steel works.

Mr. Whitwell said it was no doubt an important matter if they could in America obtain from a five-ton converter from one-half to three-fourths more than they were getting in England, and he wished Mr. Holley to tell them, whatever his opinion was, the increased output of the American converters. He had heard it said outside that room that something depended upon the fitting on of the tuyeres. No doubt one great reason why the Americans were excelling steel makers in England was because they had greatly improved upon the original Bessemer plant arrangements. He thought there was a considerable difficulty about the proposal of Mr. Williams to roll rails in tires. There was no doubt that one of the reasons of the good results obtained by Mr. Williams was because he had been exceedingly careful in the mixture of his ores.

The President said he should like to know the extent of the difference between burning the coal in an ordinary furnace and burning it in a producer for the Siemens furnace?

Mr. Williams said he should be glad if Mr. Holley could say whether there was a possibility of rolling rails tire fashion, to be straightened out at the end of the operation without reheating?

Mr. Snelus said that the West Cumberland Hematite Iron Company had some of the bottoms Mr. Holley had described, and they would be seen by the institute on the following day.

Mr. Holley said with regard to the economy of Siemens' gas furnace, they were using between 350 lb. and 400 lb. of coal for heating ingots, and about the same for reheating, and in the ordinary furnace from 800 lbs. to 1000 lbs., but they made no steam in the gas furnace. The economy of oxidation was very great. A large production of rails was economical, up to say 150 to 175 tons per day. Several spurts had been made in America, and as many as fifty heats obtained in the twenty-four hours, but beyond that point it was not economical.

Mr. Williams: With a single converter?

Mr. Holley: With one pair. The stream of ingots going into the furnace applied only to the ingots and not to the blooms. They had to be charged in rounds. The ingots heated themselves. The gas furnace did not heat them much; it simply protected them from radiation.

Mr. Williams: Then it cools them?

Mr. Holley: Possibly, to a certain extent.

Mr. Williams: The inside gets cooler?

Mr. Holley: The use of blooming rolls before one another had never been attempted in America. They considered that it would be more complex, and that the radiation would be greater than by their present system of automatic tables.

The President said there could be no doubt that in America they were doing great things in the manufacture of Bessemer steel, and their friends were not averse to tell them, not only what they had done, but also how they had done it. He thought if any one was entitled to the thanks of the meeting, it was the gentleman who had just read the last paper.

THE MANUFACTURE OF CAOUTCHOUC AND ITS INDUSTRIAL USES.*

By EUGENE PAVOUX.

From "Journal of the Society of Arts."

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity in an ordinary temperature. This special quality, to which it owes its repute, disappears almost entirely under a temperature approaching to that of melting ice, and only reappears when the india-rubber is subjected to a heat of from 30 deg. to 40 deg. (Cent.), when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends

* Translated from "La Revue des Mines" for the English edition of that work.

by taking the consistency of treacle. This sensibility to the influence of the temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200 deg. it is decomposed, and passes off in a volatile form.

Its density varies between 0.925 and 0.950.

According to Faraday, it is composed of 87.2 of carbon and 12.8 of hydrogen.

India-rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia cahuchu*, etc. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, etc.

It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india-rubber), is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay made in the shape of pears are plunged into the liquid, and afterwards passed over a fire made of the branches of trees, in order that the layer of india-rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The balls are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited and agglomerated; in this case, the mass of india-rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india-rubbers are those which are gathered in this way; such as Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption. When they are very thin they are rolled up like a skein of thread, and the appearance of the india-rubber in balls serves to remind one of a clue of worsted.

In these different states india-rubber comes to Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, etc., which have become mixed with the gum while running from the tree. This is the object of the first process in the manufacture. The raw material, after been softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a-half, then flattened between two cylinders, placed horizontally, the distance between which is regulated at will by set screws. These cylinders are of different velocities; it follows, therefore, that, independently of the pressure which the india-rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and under the continuous action of a stream of water, they are easily carried off. Under this process, which is repeated eight or ten times, every time bringing the two cylinders nearer together, all the impurities vanish, and the rubber assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a "devil," which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp pointed teeth disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute, carries along with it the grained sheet of which I have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a

compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The devil, as it is called, is usually formed with a double casing, which is heated by means of a steam jet.

I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, while if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, and this deteriorates its quality and interferes with the following operations.

On leaving the devil, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are heated internally with steam by a pipe running through a packed box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close, and exceedingly smooth. This gives the finish to the preceding operations.

Pure india-rubber is only used for special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they are to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india-rubber its various shades of gray, black, red, etc., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india-rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, while in the second it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india-rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for many purposes, among others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these, the india-rubber paste is put into a mould, which is filled more or less exactly. The exposure of this mould to a temperature varying between 125 deg. and 150 deg. causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water

is introduced, which, being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of vulcanization. The shape then (with the exception of the cutting of certain objects from sheets) should always be given previous to vulcanizing, which is the last process of manufacture.

Raw india-rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of the cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, which is most sensitive to the variations of heat, has the effect of preventing those grave inconveniences arising out of it, and of making india-rubber a substance that can be utilized under any conceivable circumstances. That is the object attained by vulcanization.

The agent employed for vulcanizing is sulphur. Its action on india rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated by a temperature of about 200 deg., produce a substance offering a good deal of resistance, and presenting almost the aspect of of india-rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with the heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to adhere.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the reaction to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india-rubber paste, which still continues adhesive. The article which is being made is put into a boiler made of sheet iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150 deg. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed of two hollow, horizontal plates, the uppermost of which is movable, and worked by screws which allow it to work up and down. The moulds are placed between these two plates, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them from pipes placed at one of the extremities, and passing at the other end through outlet pipes.

I have had fixed up in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the plates are about 7 ft. long by 4 ft. wide; their internal surface being carefully planed and dressed they give to the sheets a glossy appearance, with remarkable uniformity of character.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur de-

posited on the surface to crack, after which it is easily removed by scraping.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger size must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphuret of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only articles that are not very thick that can be subjected to this process.

It is exactly the same as regards the process which consists in the use of all alkaline sulphurets; the operation lasts about four hours. In consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india-rubber no better agent can be employed than sulphuret of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation, leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely abandoned.

Before proceeding to treat of the industrial uses of india-rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture; independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is large, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one, and demands a great deal of care to prevent the article being burnt, as it in that case would become worthless.

Indurated india-rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india-rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute."

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes may be classed in several categories, and india-rubber is used in all of them. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one or several cloths dipped in the paste, and intended to prevent the lateral extension which would take place in pressing the surfaces together as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from two to three millimetres. The same result may be obtained with felted india-rubber, that is to say, mixed with fibrous matter, such as woollen or cotton waste, etc., which by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe, it prevents the waste water from running off; it is better, therefore, to adopt the system in which the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

In making Delperdanges' joints it is necessary to use a ring forming a band, which, placed on the flanges, which are close to each other, of two pipes, is compressed and kept in its place by an iron bridle, terminated with two claws, which are pressed and brought together by a bolt. A copper sheet keeps the rubber against the pipe, where the claws are. This system has been at work in the water distribution of Lille and Valenciennes. Lastly, certain joints are made by means of a cord, either round or square, made of india-rubber alone or of felted rubber, which is placed in a groove in the two surfaces which have to be joined. The compression of this cord hermetically closes the two ends of the pipes.

India-rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of washers of rectangular shape about 2 in. in thickness, separated from each other by sheet-iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the material. To allow the passage of the buffer rod, these washers are pierced in the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet-iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoting of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their bases; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion exceedingly smooth and gentle. The tenacity, strength, and duration of the springs depend upon the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagons belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India-rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories, entrepots, etc. In this case the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appear to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The valves vary in form as well as in thickness; some are round, others are square or rectangular. The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These valves are, for the most part, made of simple india-rubber, but sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india-rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india rubber is that which has been made by M. Field,

in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by metallic pieces in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

The Perreaux valve is exclusively composed of india-rubber. The side gets gradually thinner until it comes to the sharp edge, which is split, and opens out a little under the pressure of the liquid; it closes again as soon as the piston begins to descend.

As regards pumps which are intended to pump acids, an india-rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india-rubber replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India-rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, etc., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades, worked by hand. To prevent the paste from adhering to the mandrel, care is taken to dust it first with powdered talc. Sometimes several strips are placed on top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows:—A round of india-rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india-rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have: this number of folds depends on the diameter, and increases generally with it. The outer envelope is india-rubber. By increasing the rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be pumped up, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure would inevitably cause. For this purpose a spiral is used, made of galvanized iron or copper, which is either simply placed in the interior of the tube, or imbedded in the thick part of the rubber. Generally the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are placed on a vehicle which runs on rails, and run into a boiler 20 yards long, specially prepared for them.

I manufacture a particular kind of pipe, for which I have taken out a patent. It is made of tanned hemp, with an inside casing of india-rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of $1\frac{1}{2}$ in. will bear a pressure of fifteen atmospheres, and one of $\frac{3}{4}$ in. will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, etc.

The ropes used for packing, which are

made of cloth, done over with india-rubber, are made without core, that is to say, without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather. They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India-rubber has been used for some time in covering metal rollers employed for sizing and finishing cloth; wooden rollers are replaced by metal ones, which prevent the necessity for using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woollen cloth for the external covering of the roller, one or more sheets of india-rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizing in the other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of those protuberances caused by the crossing of linen or woollen covers, presents a perfectly smooth and regular surface, and gives greater uniformity to the sizing.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, the surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side cushions by using india-rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable: I need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, etc., etc.

As regards the application of indurated rubber, we may mention the rollers for spinning frames, made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

In telegraphy, insulating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of $2\frac{1}{2}$ millimetres, so as to cut off the electric current.

If I were to point out all the applications of india-rubber to surgery and ordinary uses, I should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

PUZZOLANA, NATURAL AND ARTIFICIAL.

From "The Builder."

One of the most valuable occupations of men of science in France, is that of examining and re-examining from time to time the various substances in use in the arts, analyzing their composition, testing their positive value, and explaining the *rationale*

of their manufacture or preparation. This habit is the dire enemy of the rule of thumb, and the results being published in scientific journals of repute, are open to all the world. In this way, within a few years, most of the materials used in building, stone, marble, lime, etc., have been examined and reported on by educated and practical engineers, and others, with great advantages to those occupied in construction.

A careful essay on Puzzolana, natural and artificial, is now before us, and we proceed to give a *resumé* of the principal points for the benefit of our readers.

The puzzolanas are argillaceous compounds, which, mixed with quicklime, are rendered hydraulic, and improve the qualities of hydraulic limes. The name comes from that of the town Puzzuoli, near Naples, where the Romans obtained it in ancient times. They well knew its value, but did not understand its nature. Little was really known of it scientifically, till the end of the last century, when Vicat determined the value of the various elements of which it was composed.

The natural Puzzolanas may be divided into two classes, the volcanic, and those which are composed of natural substances not volcanic, such as siliciferous and amphibolic rocks, argillaceous sand ,and chalk containing gelatinous or semi-gelatinous silica.

The volcanic pozzolana is lava, or the produce of eruptions, the composition of which varies according to its age, the depth of the deposit beneath the soil, and the nature of the substances with which it is mixed. The essential elements are alumina, silica, peroxide of iron, and sometimes manganese, lime, soda, potash, and slight traces of other substances. It is found near extinct and active volcanoes, in the form of powder mixed with coarser substances, filled with cavities, having the appearance and porosity of pumice-stone. It is of various tints,— white, gray, yellow, brown, violet, and that of Rome is of the color of wine lees. The best kinds are found in Italy, and the principal shipping ports are Leghorn and Civita-Vecchia. The price is about 26s. to 29s. the cubic metre. It is also found in several of the departments of France, and there are large deposits in the island of Guadaloupe, to be obtained at a third of the above price. Great quantities have also been found in the island of Santorin, in Greece, richer in silica than that of Italy or Germany (Audernach), and its employment has given excellent results. The price on the spot is almost nominal.

M. L'Esler gives the following analysis of the Greek puzzolana :—

Silica	68.50
Alumina	13.31
Oxide of iron	5 50
" magnesia	0.73
Lime	2.36
Soda	4.71
Potash	3.13
Water	1.45
Chloride of sodium	0.31

The *traus*, or trass, of Holland, and of Audernach and Plaid-, in Germany, when pulverized, forms excellent puzzolana, which has been used in the great works of Holland and on the banks of the Rhine. It is said that the mortar made with it is not affected by sea-water, which, if true, deserves confirmation.

Natural puzzolana contains from 60 to 90 per cent. of clay, and 10 to 40 per cent. of lime.

Vicat analyzed all the principal known kinds of puzzolana, and we have eight results before us, of which we give the first and the last :

Roman Puzzolana.

Mixed sand	5.00
Silica	47.66
Alumina	14 33
Magnesia	3.86
Peroxide of iron	10.33
Lime	7.66
Water	7.03
Alkaline and volatile substances	4.13

Puzzolana of Audernach.

Silica	48,94
Alumina	18.95
Magnesia	2.42
Peroxide of iron	12.34
Lime	5.41
Water, etc.	11.58

In other cases the proportion of mixed sand is much larger, reaching 20 per cent., while in others there is scarcely any pure silica ; the quantity of alumina varies also from 11 to 18 per cent., and the iron from 10 to 34 per cent.

The natural non-volcanic puzzolanas are various. The siliciferous rocks, gaize, or pierre morse,—soft, light stone, found at the base of the chalk formation, and which contains silica in the gelatinous or semi-gelatinous form,—have the puzzolaneon qualities, but in a weak degree. The following is the analysis of M. Sauvage:—

Silica, soluble in liquid potash	56.00
Chloride sand, very fine	12.00

Quartzose sand	17.00
Clay	7.00
Water	8.00

The amphibolic rocks, or decomposed diorites, found in Lower Brittany, and particularly in Finisterre and Morbihan, have the appearance of coarse clay of a red or dirty white color. Their employment after a slight burning, which improves their qualities, was found tolerably satisfactory by M Avril, Inspector-General of Points et Chaussées, in the constructions connected with the Nantes and Brest canal. They contain 10 per cent. of sand, 38 to 60 per cent of silica, 23 to 29 per cent. of alumina, 10 to 22 per cent. of peroxide of iron, and very small quantities, or none at all, of lime and alkaline substances.

The sand in the vicinity of Brest, which owes its origin to the decomposition of granitic gneiss, is also used for the same purpose, after slight burning. It contains 60 per cent. of silica, 21 per cent. of alumina, 8 per cent. of iron, 6 per cent. of lime and magnesia, and nearly 3 per cent. of soluble matters.

Near Saint Assier and Musudan, in the Dordogne, there are entire hills composed of quartz-sand mixed with clay, known as *arènes*. They contain 4 per cent. of quartz or sand, 38 per cent. of silica, 20 per cent. of alumina, 12 per cent. of peroxide of iron, 8 per cent, of carbonate of lime, and 17 per cent. of water.

Some of these puzzolanas produce mortar which sets after three day's immersion, while others require fifteen days; these are extremes between which lie many intermediary qualities.

M. Vicat thus estimates the relative value of the puzzolanas made from the following clays:—

Pipe-clay and fire-clay produce puzzolana set down at the relative value of 77 to 100, average 90.50 per cent; the average composition of these clays is:—Silica, 58.25; alumina, 28 per cent.; and water 13.75 per cent.

Ochrey clay, value 70; composition on the average,—silica, 59.10; alumina 19, peroxide of iron, 10, water, 12 per cent. These two clays are burnt in the ordinary way; the following are submitted to extra heat.

Marly clay, power as puzzolana, 63; composition—silica, 30 per cent; alumina, 20 per cent.; peroxide of iron, 2 per cent.; carbonate of lime, 38 per cent; water, 10 per cent.

Brick earth, power equal to 45; composition, average—silica, 23.50 per cent.; alumina, 10.50 per cent.; peroxide of iron, 6 per cent; carbonate of lime, 24 per cent.; carbonate of magnesia, 9 per cent.; sand or quartz, 19 per cent. water, 8 per cent.

Among the puzzolanas made from burnt clay most frequently employed in public works of importance, may be mentioned that of Chartres, which has an average density of 1.200 kilogrammes per cubic metre. Mixed with two-thirds of common hydraulic lime, the mortar sets under water in three days. That made at Faquières, in the Marne, has a density of about 1,300 kilogrammes. Two parts of quicklime and one of this puzzolana, form a mortar which sets after forty hours' immersion.

Blue schists calcined, or slaty schist, of which the best deposits are found in the commune of Haineville. in La Manche, have yielded, after having been heated to whiteness, excellent puzzolana.

The employment of the ochreous earths was pointed out by Chaptal in 1797; it may be burnt either with wood or coal, and the two products are not injured in any way by being mixed.

The puzzolanas made from the various clays contain, according to Vicat, from 30 to 66 per cent. of silica, 19 to 32 per cent. of alumina; some contain 1 to 13 per cent. of lime, 4 to 14 per cent. of iron, and some as much as 14 to 30 per cent. of inert matters.

Artificial puzzolana has been made from time immemorial from broken bricks and tiles, but with very variable and generally poor results. It could not be otherwise, for the production of good puzzolana depends upon the fact of the material being burnt only to a certain extent.

Coal cinders, peat, and wood ashes, especially the last, make puzzolana of good quality; they must be sifted with care to rid them of foreign substances, and they should be stored in a dry place and only moved in fine weather.

Forge scoria pulverized and finely sifted has high qualities for producing puzzolana.

The residue from the fabrication of nitric acid with clay and azotate of potash forms the most valuable and energetic puzzolana.

The mortar in which it enters acquires a hardness superior to that of the hardest lias. The cost of the material, however, which is only used in the south of France, prevents its being much employed.

The above is a pretty complete list of the various kinds of puzzolana in use at the present day in public and private works, and in places where materials are dear they are of great service. The complete knowledge of their various qualities can only be obtained by actual experience; generally, however, it may be affirmed that the puzzolanas which are affected by acids are the most effective; but their employment in marine hydraulic works must be avoided, as salt water will completely disintegrate them.

The artificial, like the volcanic, puzzolanas, are the produce of the effect of fire in bodies essentially composed of silica and alumina.

The materials generally employed, then, are clays, the mud of seaports, docks, etc., the sands called arènes, already mentioned, argillaceous schists, ferruginous clay, ochreous earth, broken bricks and tiles, wood ashes, cinders, scoria, the residue of nitric acid, and certain amphibolic rocks in a state of decomposition. The burning is effected in the same way as that of bricks and lime, the material being sometimes formed with lumps, and sometimes burnt in a state of powder or irregular fragments. In the last case, they are treated in reverberatory furnaces. This plan, which was employed by M. Pesot, saves the cost and labor of pulverization after burning, which is always greater than when effected previously.

M. Vicat strongly recommends a system which consists in drying the clays in the sun, or by means of hot air, and then reducing them to powder in a mill, on the principle of those used for coffee and spices, or with stones, and then exposing the powder to sufficient heat to drive off all the moisture which it contains. He employed for this purpose a series of hollow cylinders in cast iron, placed near to each other, in which the powder is introduced, the cylinders being so arranged as to pass successively through a conduit, formed of non-conducting materials, which receives a current of air heated to 600 deg. or 700 deg. centigrade. A slight inclination is given to this conduit, so that the slightest effort is sufficient to cause the cylinders to move through it by merely removing that one at the lower end and placing a fresh one at the other. The powdered clay only partially fills the cylinder, so that it rolls over itself as the latter proceeds, and all the particles come in contact with the hot air. By this means the puzzolana obtained possesses all the qualities of which it is capable. It must be noted, however, that each kind of clay demands a different degree of heat, which can only be settled by practice.

Clay is transformed into puzzolana when it has lost the water it contained, and also the faculty of making a paste with water. M. Vicat designates "normal burning" that which has been conducted under the following conditions:—1. The previous reduction of the substance to be burned to fine powder; 2. The action of fire limited to 600 deg. or 700 deg. centigrade, and maintained till the aluminous hydrosilicate becomes anhydric; 3. The admission of air during the whole operation. "Super-normal burning" he describes as that which, without being carried above 750 deg. centigrade, has been sufficiently prolonged to decompose the carbonate of lime contained in the clay.

The same author, from a large number of experiments and observations, derives the following conclusions:—

1. The rank which a substance holds as a material for puzzolana depends almost precisely on the proportion of argillaceous matter which it contains.

2. Other conditions being equal, that clay is the best which contains the largest proportion of silica, without, however, passing a certain limit, so as not to exclude all the aluminium.

3. Of various puzzolanas of equal proportions and principles, that which has the greatest specific gravity is to be preferred.

4. "Normal burning" develops most fully the qualities of all puzzolanas made from materials free of carbonate of lime, or not containing more than 12 to 15 per cent. of it.

5 In all other cases the "supernormal burning" is more effective.

The methods of burning as well as the qualities of the puzzolana vary *ad infinitum*. General Trussard, who has given great attention to this subject, prefers clays which contain about equal quantities of silica and alumina, and only 0.4 or 0.5 per cent. of carbonate of lime. Pottery clays are often of this character. The General recommends them to be treated in the same manner as bricks, to make them up into lumps, larger or smaller in proportion to the lime they contain, and afterwards to reduce them to very fine powder by means

of silk bolters, as the finer the powder the greater is the effect of the puzzolana.

M. Saint-Léger in his work at Meudon, mixes with the clay a quarter of its volume of quicklime in the form of paste, and he obtains artificial puzzolana far more energetic than the best natural puzzolanas, and which remains unaltered for an indefinite time, an advantage which the hydraulic limes do not possess.

Following the indications above given, excellent puzzolana may be made anywhere, when the composition of the material at hand has been ascertained. M. Berthier furnishes the following ready method of analyzing clays:—"When the clay contains lime the latter is always in the form of carbonate; its presence may therefore be easily ascertained by pouring a few drops of any acid or vinegar on to a piece of the clay in water, when effervescence will take place in proportion to the amount of the lime present. The analysis of calcareous clays is the same as for argillaceous limestone."

LIGHTING RAILWAY CARRIAGES.

From "The Engineer."

Possibly the most imperfect detail in our railway system is the method adopted of lighting the carriages. We do not allude to the windows, although there is plenty of room for improvement even as regards these, but to the provision of artificial light for night travelling. Apparently there is no reason why a railway carriage should not be as well lit as a drawing-room. The space to be lighted is small, and the expense must in any case be very little as compared with that of other items essential to railway transit. But as a matter of fact, even on the best managed railways, the light supplied by the regulation lamp is simply wretched. To read at night is impossible, and the utmost that has been effected is to render darkness visible by the use of a heavy, lumbering, evil-smelling appliance, the cost of which is by no means small, while the waste of material in the shape of oil and wicks which attends its use is absurdly great. The public complain loudly and reasonably. But there is little cause to doubt that the railway companies are perfectly aware of the disadvantages of the existing system—directors constantly travel by rail—and it is not to be disputed that many attempts have been made to provide better lighting apparatus than that with which we are all but too familiar. Many difficulties have stood in the way, however. The great defect of the existing lamp is that oil to be burned properly requires a chimney; but it has been found impossible to use argand lamps in railway carriages. They are exposed to incessant draughts, and the chimneys break continually; and the labor entailed besides, even if the chimneys stood, in keeping them clean, would be inimical to the adoption of the forced draught system of combustion. It does not appear, indeed, that so long as oil is to be used for illumination, anything much better than the existing lamp, or more satisfactory in handling, can be adopted. The obvious way out of the difficulty lies in using gas. How far this is a satisfactory remedy any one in the habit of travelling on our metropolitan railways can judge. The gas is carried under the ordinary pressure in bags on the top of the carriages, and for short runs say four or five miles, the plan answers tolerably well; but air is apt to get in with the gas, and a very small admixture of air will remove a large proportion of the lighting power of the flame. It has been proved that 5 per cent. of air mixed with gas will reduce 16-candle to little over 10 candle power, and this defect is very apparent on the Metropolitan railway; and besides the light is not so steady as could be desired. Imperfect as the application of gas to lighting railway carriages still is as a system, it is still certain that it gives results much better than oil as regards the comfort of passengers. But unfortunately coal gas cannot be used for long runs. To carry a reservoir or gasholder large enough to last for a run to Holyhead from Euston, for example, would be impossible. A large vehicle would be required to convey the gasholder alone. Many attempts have been made therefore to use gas under pressure, so that a large number of cubic feet may be stored in a small space, but hitherto these attempts have all proved abortive, because coal gas when compressed appears to deposit carbon, and loses nearly all its lighting powers;

and, in addition, it is found to be very difficult to keep coal gas at all under pressure, as it leaks slowly through vessels which would be quite air-tight. There is a way out of the trouble, however, and experiments now being tried on the London and North-Western Railway, to which we wish to call attention, have given results so satisfactory that there is reason to hope that gas will supersede oil on our railways as effectually as it has done in our dwelling-houses.

Herr Julius Pintsch, of Berlin, has long been known on the Continent as a maker on a great scale of gas-meters and gas fittings. As far back as 1867 he placed himself in communication with the officials of the Niederschlesisch-Märkische Railway, and proposed a new system of lighting railway carriages with gas. They co-operated cordially with him, and after more than three years of experimenting all difficulties were overcome, and the Pintsch system of lighting has been adopted regularly on the railway in question, and is being rapidly applied on eight other lines, including that from St. Petersburg to Moscow, and the Austrian "Nord-Kaiser Ferdinand." The system consists in fitting each carriage with a reservoir of wrought iron, into which gas is forced to a pressure of about six atmospheres, or 90 lbs. The gas then flows from this reservoir through a very simple and ingenious regulator to a lamp made of cast iron and of the simplest possible construction, which is placed in the roof of each compartment in the ordinary way Now all attempts to use coal gas in this way have been failures, for the reasons already explained; but Herr Pintsch employs oil gas, which is quite unaffected by the pressure when made as he makes it. The oil-making apparatus consists of a double-story retort. The oil, which may be whale oil, dead oil, common blue shale oil, coarse petroleum, fat—in fact, almost any cheap hydrocarbon will do—is introduced in a continuous stream into a tray in the upper retort. Here it becomes partially volatilized, and then circulating through the lower retort the process is complete, and the gas is passed through a short length of pipe provided with a tarwell, and thence to a purifier charged with sawdust and lime, and thence to a gasholder. On the Niederschlesisch-Märkische Railway the cylindrical portions of two old locomotive boilers with flat ends riveted in, are used to hold the gas, which is pumped in by a small compressing engine operating not on the gas direct'y, but on oil which rises and falls with the pistons in a way which will be readily understood. The gas is pumped into these at a pressure of 90 lbs. At the side of a convenient piece of rail several small stand pipes are erected, which are in communication with the compressed gas reservoirs, and from these, by the aid of a stout india-rubber hose and coupling, the reservoirs under the carriages are filled much as the bags are filled on the Metropolitan Railway. About eight minutes are required to supply a long train with gas. The gas is led to the lamps on the roofs by small pipes ¼ in. bore, and the fittings are so contrived that the burner, which is of the batswing type of steatite, is readily turned back out of the basin of the lamp to permit the latter to be cleaned. The glass bowls can be replaced, if broken, in a few minutes. A reflector is placed over each flame, and through this reflector passes a flat chimney, the air for combustion comes down outside this chimney, finding its way in through small perforations, and at the highest speeds no flickering of the flame is perceptible. This lamp is in itself worth the attention of railway companies, even if it were to be used with oil, as it possesses many advantages over the ordinary lumbering contrivance. Before the gas reaches the lamp, however, it has to pass through the regulator, and this is one of the essential features of the whole design. It consists of a small cast-iron box placed under each carr age out of the way. This vessel is divided into two portions by a diaphragm of dressed sheep-skin, which is partially supported by a small lever and spring. The lever acts on a little conical valve, and the moment the pressure becomes too much the diaphragm rises and shuts off the gas. We have seen this regulator tested, and its action, we can say from personal observation, is perfect; and it is found that the gas improves the quality of the leather, being, as it is, free from acids and rather oily in its nature. It is unnecessary here, we think, to enter into farther descriptive details.

As regards the results, it will be asked, first, for how many hours can gas be carried? And secondly, what is the light given? As regards the first point, we may state that a composite carriage has been fitted up on the London and North-Western Railway. This carriage has been run-

ning for some weeks. It carries gas enough in a receiver, made of wrought iron $\frac{3}{8}$ in. thick, 5 ft. 10 in. long, and 1 ft. 4½ in. diameter, at five atmospheres pressure, to run twice to Holyhead and back, sufficient gas being left for a farther run to Chester, if necessary. In other words the carriage carries gas for over 1000 miles. It may be imagined that the gas would waste away, or lose its illuminating power during so long a run, but this is not the case. We found the carriage after two runs to Holyhead and back, and having stood at Euston three days, still carrying pressure of one atmosphere, as tested by a Bourdon gauge, put on for the purpose of ascertaining the pressure. But the point has been set at rest by Herr Gust, of the Niederschlesisch Märkische Railway, who filled a receiver, and left it untouched for eight months, at the end of which time it was found to contain gas under a considerable pressure, and of good illuminating power. The apparatus in use at Euston for making the gas is temporary and of the rudest description; two pieces of 3in. wrought iron piping about 4ft. long constitute the retorts, which are heated by coke burned in a sheet iron furnace. The purifier is about as big as a hat, and the gas-holder was made by a tinsmith; the oil used is that drained from the carriage-lamp bowls, and is, we need not say, sufficiently filthy stuff; the pumping is done by a couple of men. As regards the second question to which we have referred, we may state that the oil gas is probably of nearly 40-candle power, and the light in the carriage is about 7 to 4 in favor of the gas.

We have spoken thus fully of Herr Pintsch's system, because it appears to have been well and carefully thought out. The labor involved is partly proved by the enormous number of patents which have been taken out from time to time to cover improvements. The use of this system on the Continent is an accomplished fact, and the results obtained on the London and North-Western Railway really appear to leave nothing to be desired but its more extended adoption. Of course, it is quite possible that better systems of lighting may be used, but we venture to think they have to be yet invented. We have said nothing about relative cost, that is a matter of detail little affecting the public, and not possessing scientific interest enough for discussion here; we believe, however, that the expense of the light is found on the Continent to be about 70 per cent. cheaper than oil lamps.

THE COLOSSEUM OF ROME.

From the London "Times."

The excavations in the Colosseum have now reached a certain degree of completion, and far exceed in general interest any of the important works of exploration which, since the commencement of this century, have restored so much of the remains of the ancient city to light. Every Sunday and holiday afternoon numbers of people of all classes flock there to examine, discuss, and gaze in wondering admiration at the gigantic constructions, gradually being disinterred, so colossal in their dimensions as almost to throw into the shade that portion of the edifice which, for the last six centuries, at least, has been looked upon as fully justifying its name of Colossus among buildings.

It is scarcely an exaggeration to say that what is now being revealed excites as much wonder in all who look upon it for the first time as the building in all its integrity did in the Saxon pilgrims when they burst forth with the well-known exclamation recorded by the venerable Bede. But it is no mere massive foundation which has been laid bare; it is no less than 21 ft. of the interior of the edifice itself—buried till now under a mass of accumulation—which has been restored to light, and with it much is made clear that has hitherto puzzled both the learned and unlearned alike. Until now the Colosseum has been an unsolved riddle in many respects. We knew that it was built for the exhibition of wild animals, as a place where they could be shown in numbers to the people, and where they could be hunted and made to fight with each other or with men; that gladiatorial shows on an enormous scale were given here, and that many martyrs testified with their blood on the arena. The ranges of seats rising one above the other could be fully recognized, utterly ruined as they are, and the admirable arrangement of the

eighty different flights of steps, intersecting and yet not interfering with each other as they conducted to the seats, could be perfectly understood. But how were the animals brought into the arena? Where were they kept? What was the stage mechanism of this enormous amphitheatre? These are questions asked by all, but which have never been answered except by imperfect explanations founded on conjecture. We may accept the explanation that the animals were kept in great *vivaria* on the Cœlian and near the Porta Maggiore, but that they were brought thence into the amphitheatre in cages was far from satisfactory.

To test this by one of many records, how, if they were introduced in cages, could 100 lions have bounded together upon the arena with a roar which made the building shake, as we are told by Vopiscus was the case during the games given by the Emperor Probus? And then what confusion there must have been outside, or, rather, how was confusion prevented between the actors and the audience on their way into the building, between, on the one hand, the thousands flocking into the amphitheatre together with the many thousands more who, not fortunate enough to obtain tickets, gathered in the open area around for the excitement of listening to the rousing of the animals, the cries of the victims, and the shouts of the spectators; and, on the other, the bands of gladiators, with all the multitude of men requisite to guard a number of savage beasts maddened by hunger? The edifice was surrounded by a portico divided into eighty arches, every arch, with the exception of two only, forming an entrance to the seats, including the *pulvinaria;* the numbers corresponding to the tickets are still visible on the keystones of those remaining. The two arches, one at each end of the longer axis, were supposed to be the only part reserved for the entrance of the gladiators and the animals; but, with a public entrance through the arch on each side of these, it was difficult to understand how so circumscribed an area—however well it might have been railed off—could have been sufficient for all the work "between the wings," for the entry of the army of men and the hundreds of wild beasts, and the exit of the dead of whichever kind. These are problems which have puzzled all who have considered the subject, however slightly, but which these excavations have now completely solved.

At the beginning of this century extensive excavations were made on the arena, but with no other result than to increase the difficulties they were intended to remove. Immediately beneath the modern surface a network of walls was found intersecting the area in various directions. Some maintained that these were constructions of a late period superimposed upon the arena, while others insisted that they were subterranean, and formed the dens in which the animals were kept and the corridors through which they were introduced upon the level above. A furious controversy was carried on; but, as the construction of the Roman buildings was a subject then but imperfectly understood, no authoritative conclusion was arrived at; and as the place during the rainy seasons got flooded with water, which remaining stagnant and slowly evaporating became a cause of unhealthiness to the city, the excavation was filled in again in 1813, after having remained open for about ten years. Some months ago Signor Rosa determined to make another attempt to clear up the mystery, and now, 21 ft. below what has so long been looked upon by many as the arena, he has discovered its veritable level, paved with *opus spicatum*, or herring-bone work, and leading from it a series of enormous corridors with immense chambers, where the business of the amphitheatre was prepared—the "behind the scenes," in fact. He has gone deeper than the first excavations were carried, and it is now evident that they were confined to the ellipse within the podium.

We must wait until the entire area of the arena is cleared before it can be positively decided whether the constructions superimposed upon it are remains of the work of the Frangipani, who converted the Colosseum into a fortress, or if they were built, as is quite possible, to raise the arena above its original level. In the mean time, however, there can no longer be any doubt that, for whatever purpose they were constructed, they are the work of a very late period, and have nothing whatever to do with the edifice as originally built by the Flavian Emperors, and as it must have remained for a considerable period. We may therefore dismiss them for the present.

It is generally supposed that the low wall at the back of the "stations," which were erected in the middle of the last century,

was the front of the podium; but it is now found that those stations stood on its level, that the wall behind them was the back and not the front, and that a platform 3 metres 70 centimetres in width extends from it to the edge overlooking the arena 7 metres below. From the front of the podium, at about two-thirds down to the level of the arena, a series of gigantic brackets of travertine project at regular intervals, and evidently extend along the entire circuit. On clearing the front of the podium down to the level of the arena, at the end of the larger axis of the ellipse towards the Lateran, three great archways were found, opening under it from the arena, but completely filled with an accumulation of solid clay, such as would be deposited by an inundation of the Tiber. The side archways measure 3 metres, 85 centimetres in width, and that in the centre 2 metres 28 centimetres. Opening the middle archway, it was found to be a corridor extending from the amphitheatre. As the excavators tunnelled along it they disclosed one after the other a series of flat arches, perhaps I should say architraves, massively constructed of great blocks of travertine, and held together by colossal keystones. This corridor, continuing in a straight line, has been cleared to the length of 100 metres without the termination yet being found; but at the distance of 85 metres from the arena, and about 12 beyond the exterior of the edifice, another corridor of the same dimensions branches off from it to the right, in the direction of the caverns on the Cœlian, believed to have been a *vivarium*. Exploration was then commenced through the side archways, and they were also found to be the openings of corridors radiating from that in the middle to the length, however, of only 24 metres, when they turn at right angles, the one to the right, and the other to the left, and communicate with a long corridor between them; the ground-plan being that of a blunt wedge with the end towards the arena, or of a dovetail with the end from it. I may remark here that the floor of the side corridors is on a level with the arena, while that in the centre is about one metre higher.

One great advantage the Government possess in having a man like Signor Rosa at the head of the executional department is, that being an engineer of no inconsiderable skill, he goes to work in a thoroughly scientific manner. Having created a sufficiently large receptacle where water could gather, he lost no time in taking the requisite precautions against the first spell of wet weather inundating the excavation and interrupting his work, to say nothing of its possibly causing malaria. Considering that naval shows having been given in the amphitheatre implied the necessary arrangements not only for flooding the arena, but also for letting off the water afterwards, he commenced excavations still deeper, and soon found a well-built *cloaca*, about 2 metres in height, immediately beneath the long corridor I have mentioned, and a mouth opening with it between the floor of this corridor and that of the arena, with several bars of the metal grating to prevent solid bodies washing down still *in situ*. This *cloaca* has been sufficiently cleared to provide an outlet for any water that might accumulate, and is in itself a solution of the somewhat debated question whether the amphitheatre was used for a *naumachia* or not.

When the side corridors were entirely cleared, a series of circular holes from 17 to 30 centimetres in diameter were found along the central line of each. On examination these proved to be large sockets of solid golden-colored bronze. Each is a block of metal 41 centimetres square, with dovetails projecting on two sides to hold them firm on the blocks of stone into which they are set, the depth of the sockets being from 25 to 30 centimetres, and each having a convex bottom.

Signor Rosa is of opinion that these side corridors were, so to say, the docks for the galleys used in the naval shows, and that the sockets were to hold upright posts to which they could be moored and kept erect till there was sufficient water for them to float. Considering, however, that in each corridor of 24 metres in length there are six of these sockets, at distances apart gradually lessening from 4 metres 80 centimetres at the opening, to 2 metres 50 centimetres at the end, this can scarcely be possible, and I am inclined to think, as the sockets have all the appearance of having been made for pivots to turn in them, that they mark the positions of swing gates, which, when closed, formed so many pens, one behind the other, from which groups of animals could be let loose in succession on the arena. As I have mentioned, these corridors were filled with solid clay, no doubt deposited during inundations of the Tiber,

the water washing back through the *cloacæ*, as it does now when the Pantheon is flooded, and, from these great bronze sockets being *in situ*, and no holes having been made in the walls here, as in the upper part of the building to abstract the metal clamps, it is evident that this portion of the amphitheatre must have become covered with deposit at a comparatively early period, possibly also immediately after an exhibition of animals had been given, and before all the bodies of those slaughtered had been removed, for a number of bones of wild beasts were found in one of the corridors.

Describing the end of the longer axis of the building towards the Lateran, where these discoveries have been made at the east end—it is very nearly—your readers will understand me when I say that the whole of the front of the podium has been cleared as far as the northern end of the lesser axis—that towards the Esquiline. Here, exactly in a line with the axis, another corridor, corresponding in size to those at the east end, opens from the arena. This has not yet been cleared, but an opening has been made outside the building, and it is seen to extend inwards and outwards. There are lateral corridors here, and, as there was no *vivarium* to the north, we may suppose this to have been an entrance for the gladiators and *bestiarii* only, and possibly for the removal of the dead bodies.

Considering the perfectly symmetrical plan upon which the Colosseum was built, we may reasonably infer that on the south side towards the cœlian, another corridor will be found corresponding to that on the north, and at the west end towards the forum three others, or, at any rate, one other, corresponding to those at the east. Your readers will remember that on the side towards the cœlian a passage beneath the modern level was known to exist, and in fact a portion of it has been open from above for many years, but it passes under the fourth arch from the centre towards the east. From its mosaic pavement and the handsome stucco ornaments found on the vaulting it is believed to be the private passage built by Commodus, and in which Quintianus made the attempt to assassinate him. The excavation has not been carried sufficiently far on that side to show if it opens on the arena; but its course is being followed on the outside of the building, and it is seen that, after continuing onwards for a short distance, it turns, nearly at a right angle, towards the east in the direction of the branch which turns to the south from the long corridor running eastward. The direction of these passages would seem to indicate their junction at a point further on, so that together they would lead to and from the *vivarium* on the Cœlian; but as it can scarcely be supposed that the decorated corridor of Commodus led to a menagerie—and, in fact, there is no positive authority for the modern conjecture that one was situated there—it is probable that these corridors led to the Gladiatorial Schools, the *Ludus Matutinus* and *Gallicus*, and the *Spoliarium*, *Laniarium*, and *Armamentarium*, mentioned in the Regionary Catalogues. This, however, in the mean time, is but conjecture, and the object of my letter is to report ascertained facts.

These excavations have established beyond doubt that the arena was not a "movable platform," with dens or receptacles below from which the beasts were introduced upon it; that the constructions below the modern level which led to and seemed to justify this supposition belong to a very late period; that they are superimposed upon the arena, and for whatever purpose they were built they are far too small to have contained the larger animals, even singly; that the arena was a solid floor, and that upon it debouched a number of great corridors, having a series of lateral chambers, sufficiently large to justify the records of the number of animals exhibited together; while the *cloaca* which has been found with a grated opening proves that naval shows were given in the building.

There is no longer any difficulty in understanding all the details connected with the spectacles given in the amphitheatre. The enormous openings yawning upon the arena, give a vivid reality to the descriptions of the scenes once enacted within these walls; but little imagination is now wanted to repeople the ranges of seats with the mighty concourse which once filled them, or to appreciate the intense, the breathless expectation with which, as the boys who scattered the sand left the arena, the 87,000 spectators listened to the echoing roars of the animals and watched the mouths of those weird tunnel-like corridors for the first actors to bound upon the scene.

THE CONDITIONS OF THE MANUFACTURE OF EXTRA-SILICEOUS PIG IRON IN THE BLAST FURNACE.

By M. SAMSON JORDAN.

From the "Universal Review of Mining."

Those engineers who are accustomed to the management of blast furnaces, and to the manufacture of pig iron of a special character and especially those who have had to supply the pig for conversion into steel by the Bessemer process, have been obliged to make themselves acquainted with the conditions under which is produced that class of pig iron denominated "chaud," that is to say, one that contains from 1½ to 2½ per cent. of silicon; some have, indeed, run extra-siliceous pig, containing, for instance, 7 to 8 per cent. of the metalloid. These last-named classes of pig iron have an appearance peculiar to themselves; the brightness of their newly-made fracture increases in proportion to their percentage of silicon; their texture is coarse, but the granules are slightly rounded, without any projecting point; the brightness resembles that of pure silicon; the finger, on being passed over the surface of the fracture, experiences a sensation quite different from the rugose feel of the fracture of gray pig, rich in graphite. Moreover, in the works which produce them, this extra-siliceous iron has obtained the name of "glazed pig" (in France *fontes glacées*).* The following is an analysis of pig iron of this class run from the blast furnaces of Towlaw, near Newcastle:

Carbon	2.39
Silicon	5.73
Sulphur	0.12
Phosphorus	0.13
Titanium	0.02
Nickel and cobalt	0.04
Manganese	1.33
Metallic iron	90.21
	99.97

I have made myself acquainted with the details of the production of extra-siliceous pig at several works, among others that of Heerdt, near Dusseldorf, and the publication of the following details may prove useful:

On the occasion of an accident which necessitated extensive repairs to the tube which led to the blast to the six tuyeres of his blast furnace, M. Butgenbach, the manager of the Heerdt Works, was obliged, in order to keep his furnace in blast, to work for eight days with only three tuyeres and a slight pressure (10 centimetres of mercury, instead of 15 to 18 centimetres as was usual); the temperature of the blast was found to have risen considerably (from 500 deg. to 600 deg.) on account of its diminished quanity and the magnitude of the appliances for heating it. The number of charges was considerably reduced, and, in order to run no risks, so also was the weight of each charge of ore, 1250 kilogrammes (yielding on an average 38 per cent. of metallic iron) being put in with 1,000 kilogrammes of coke and 600 kilogrammes of flux (*castine*).

The following are the proportions of the fusible substance contained in this charge, which went to slag:—

Silica	50	Oxygen	26
Alumina	16		
Lime	33	Oxygen	17.6
Protoxide of manganese	1		
Proportion of the oxygen of the silica to the oxygen of the bases			26 : 17.6

This charge yields a viscous slag, which, when cold, became vitreous and translucid like slags rich in alumina, the color being a bluish opal white.

The corresponding metal was very "lively," and retained a large amount of heat; it ran along the channel formed in the sand in a uniform stream, like molten lead, without the least bubbling, and without scintillations; it filled the moulds exactly without adhering to the sand. When cold, it was very brittle, and had no metallic ring. It was a typical "glazed pig," and its analysis gave:—

Silicon	7.90
Phosphorus	0.72
Carbon	2.60

The corresponding consumption of coke was 2,100 kilogrammes for every 1,000 kilogrammes of pig iron.

In works using aluminous ores, as in those of Aveyron, where Mondalazac ore (which contains 11½ per cent. of alumina with only 10 per cent. of silica and 15 per

* This pig iron has nothing in common with looking-glass pig, (*fonte miroitante*), and it is in error that this equivalent is given for "glazed pig" in certain French works on metallurgy.

cent of lime and magnesia) is made use of, very siliceous pig is, as a rule, turned out, which wastes very much in puddling. Since their blowing in, the blast furnaces have always produced extra-siliceous pig iron which is denominated "flat grained" (*à grain plat*), and which contains 6 and even 7 per cent. of silicon. The production of this pig from a charge of aluminous ore always leads to a large consumption of coke.

At the St. Louis Works, near Marseilles, which generally turns out pure gray pig iron, with slag of nearly the following composition—

Silica	33
Alumina	15
Lime	50
Other substances (magnesia, manganese, &c.)	2

the iron contains, as a rule, only 1 to 1½ per cent. of silicon. In order to obtain very "lively" Bessemer pig, containing about 4 per cent. of silicon, it is necessary to modify the charge so as to obtain— *

Silica	40
Alumina	19
Lime and mangesia	41

Having noted these and other analogous circumstances, I am in a position to state that the following are the conditions in the blast furnace suitable for turning out an extra-siliceous pig iron:—

1. Slow, but very hot blast.
2. Siliceous, but, at the same time, very aluminous charge.

It is necessary that the blast be hot to allow of the union of the silicon with the metal (it is more refractory than the pig simply carburetted); it is necessary that it be slow in order to allow time for the reduction of the silicon in the presence of the carbon and of the iron to take place to a sufficient extent. It is necessary that the charge should be but slightly calcareous in order that the affinity of the lime for the silica should not prevent the reduction of the latter; and, for the same reason, it is necessary that the alumina should be present in sufficient quantity to neutralize still further the basic action of the lime playing the part of an acid, and probably forming one of the aluminates investigated by Berthier.

*The manufacture of a special pig depends almost entirely on the composition given to the slag by the charge, provided that the blast be regular and sufficiently hot.

FORCES DUE TO DIFFERENCE OF TEMPERATURE.

From "Nature."

It has been noticed by several philosophers, and particularly by Mr. Crookes, that, under certain circumstances, hot bodies appear to repel and cold ones to attract other bodies. It is the object in this paper to point out and to describe experiments to prove that these effects are the results of evaporation and condensation; and that they are valuable as evidence of the truth of the kinetic theory of gas, viz., that gas consists of separate molecules moving at great velocities.

The experiments of which the explanation will be given were as follows:

A light stem of glass, with pith-balls on its ends, was suspended by a silk thread in a glass flask, so that the balls were nearly at the same level. Some water was then put in the flask, and boiled until all the air was driven out of the flask, which was then corked and allowed to cool. When cold there was a partial vacuum in it, the gauge showing from ½ to ¾ of an inch pressure.

It was now found that when the flame of a lamp was brought near to the flask the pith-ball which was nearest the flame was driven away; and that with a piece of ice the pith was attracted.

This experiment was repeated under a variety of circumstances, in different flasks and with different balances, the stem being sometimes of glass and sometimes of platinum; the results, however, were the same in all cases, except such variations as are about to be described.

The pith-balls were more sensitive to the heat and cold when the flask was cold and the tension within it low, but the effect was perceptible until the gauge showed about an inch, and even after that the ice would attract the ball.

The reason why the repulsion from heat was not apparent at greater tensions was clearly due to the convection currents which the heat generated within the flask. When there was enough vapor, these currents carried the pith with them; they were, in fact, then sufficient to overcome the forces

which otherwise moved the pith. This was shown by the fact that when the bar was not quite level, so that one ball was higher than the other, the currents affected them in different degrees; also that a different effect could be produced by raising or lowering the position of the flame.

The condition of the pith also perceptibly affected the sensitiveness of the balls. When a piece of ice was placed against the side of the glass, the nearest of the pith-balls would be drawn towards the ice, and would eventually stop opposite to it. If allowed to remain in this condition for some time, the vapor would condense on the ball near the ice, while the other ball would become dry (this would be seen to be the case, and was also shown by the tipping of the balance, that ball against the ice gradually getting lower). It was then found when the ice was removed that the dry ball was insensible to the heat, or nearly so, while that ball which had been opposite to the ice was more than ordinarily sensitive.

If the flask were dry and the tension of the vapor reduced with the pump until the gauge showed $\frac{3}{4}$ of an inch, then, although purely steam, the vapor was not in a saturated condition, and the pith-balls which were dry were no longer sensitive to the lamp, although they would still approach the ice.

From these two last facts it appears as though a certain amount of moisture on the balls was necessary to render them sensitive to the heat.

In order that these results might be obtained it was necessary that the vapor should be free from air. If a small quantity of air was present, although not enough to appear in the gauge, the effects rapidly diminished, particularly that of the ice, until the convective currents had it all their own way. This agrees with the fact that the presence of a small quantity of air in steam greatly retards condensation and even evaporation.

With a dry flask and an air-vacuum, neither the lamp nor the ice produced their effects; the convection currents reigned supreme, even when the gauge was as low as $\frac{1}{4}$ inch. Under these circumstances the lamp generally attracted the balls and the ice repelled them, i. e., the currents carried them towards the lamp and from the ice, but by placing the lamp or ice very low the reverse effects could be obtained, which goes to prove that they were the effects of the currents of air.

These experiments appear to show that evaporation from a surface is attended with a force tending to drive the surface back, and condensation with a force tending to draw the surface forward These effects admit of explanation, although not quite as simply as may at first sight appear.

Although there must always be reaction corresponding to the visible motion, whenever vapor is driven off from a surface, this visible motion is too small to account for the forces under consideration. But although it appears to have escaped notice so far, it follows as a direct consequence of the *kinetic* theory of gases that whenever evaporation take place from the surface of a solid body or a liquid, it must be attended with a reactionary force equivalent to an increase of pressure on the surface, which force is quite independent of the perceptible motion of the vapor. Also condensation must be attended with a force equivalent to a diminution of the gaseous pressure over the condensing surface, and likewise independent of the visible motion of the vapor. This may be shown to be the case as follows:—

According to the kinetic theory the molecules which constitute the gas are in rapid motion, and the pressure which the gas exerts against the bounding surface is due to the successive impulses of those molecules, whose course directs them against the surface, from which they rebound with unimpaired velocity. According to this theory, therefore, whenever a molecule of liquid leaves the surface henceforth to become a molecule of gas, it must leave it with a velocity equal to that with which the other particles of gas rebound—that is to say, instead of being just detached and quickly passing off into the gas, it must be shot off with a velocity greater than that of a cannon-ball. Whatever may be the nature of the forces which give it the velocity, and which consume the latent heat in doing so, it is certain, from the principle of conservation of momentum, that they must react on the surface with a force equal to that exerted on the molecule, just as in a gun the pressure of the powder on the breech is the same as on the shot.

The impulse on the surface, from each molecule which is driven off by evaporation must therefore be equal to that caused by the rebound of one of the reflected mole-

cules (supposing all the molecules to be of the same size), that is to say, since the force of rebound will be equal to that of stopping, the impulse from a particle driven off by evaporation will be half the impulse received from the stopping and reflection of a particle of the gas. Thus the effect of evaporation will be to increase the number of impulses on the surface; and, although each of the new impulses will only be half as effective as the ordinary ones, they will add to the pressure.

In the same way, whenever a molecule of gas comes up to a surface and instead of rebounding is caught and retained by the surface, and is thus condensed into a molecule of liquid, the impulse which it will thus impart to the surface will only be one-half as great as if it had rebounded. Hence condensation will reduce the magnitude of some of the impulses, and hence will reduce the pressure on the condensing surface.

This explanation is then put in a mathematical form, and the paper proceeds.

Applying these results to steam, we find that at a temperature of 60 deg. the evaporation of 1 lb. of water from a surface would be sufficient to maintain a force of 65 lbs. for one second.

It is also important to notice that this force will be proportional to the square root of the absolute temperature, and consequently will be approximately constant between temperatures of 32 deg. and 212 deg.

If we take mercury instead of water, we find that the force is only 6 lbs. instead of 65; but the latent heat of mercury is only $\frac{1}{30}$ that of water, so that the same expenditure of heat would maintain nearly three times as great a force.

It seems, therefore, that in this way we can give a satisfactory explanation of the experiments previously described. When the radiated heat from the lamp falls on the pith its temperature will rise, and any moisture on it will begin to evaporate, and to drive the pith from the lamp. The evaporation will be greatest on that ball which is nearest the lamp, therefore this ball will be driven away until the force on the other becomes equal, after which the balls will come to rest, unless momentum carries them further. On the other hand, when a piece of ice is brought near the temperature of the pith it will be reduced, and it will condense the vapor and be drawn towards the ice.

The reason why Mr. Crookes did not obtain the same results with a less perfect vacuum was because he had then too large a proportion of air or non-condensing gas mixed with the vapor, which also was not in a state of saturation. In the experiments the condensable vapor was that of mercury, or something which required a still higher temperature, and it was necessary that the vacuum should be very perfect for such vapor to be anything like pure and in a saturated condition. As soon, however, as this state of perfection was reached, then the effects were more apparent than in the correspondiug case of water. This agrees well with the explanation; for, as previously shown, the effect of mercury would for the same quanity of heat be three times as great as that of water; and besides this, the perfect state of the vacuum would allow the pith (or whatever the ball might be) to move much more freely than when in the vapor of water at a considerable tension.

Of course the reasoning is not confined to mercury and water; any gas which is condensed or absorbed by the balls when cold in greater quantities than when warm would give the same results; and as this property appears to belong to all gases, it is only a question of bringing the vacuum to the right degree of tension.

There was one fact connected with Mr. Crookes' experiments which, independently of the previous considerations, leads me to the conclusion that the result was due to the heating of the pith, and was not a direct result of the radiated heat.

In one of the experiments exhibited at the Soirée of the Royal Society, a candle was placed close to a flask containing a bar of pith suspended from the middle; at first the only thing to notice was that the pith was oscillating considerably under the action of the candle; each end of the bar alternately approached and receded, showing that the candle exercised an influence similar to that which might have been exercised by the torsion of the thread had this been stiff. After a few minutes observation, however, it became evident that the oscillations continued instead of gradually diminishing, as one naturally expected them to do; and, more than this, they actually increased, until one end of the bar passed the light, after which it seemed quieter for a little, though the oscillations again increased until it again passed the light.

The explanation given is that, owing to the slowness with which the pith takes in

end gives out heat, its ends will on the whole be hotter while receding from than while approaching the candle, and hence the force, as a mean, will be greater on that end which is receding, and there will be a continual oscillation.

Since writting the above paper, it has occurred to me that, according to the kinetic theory, a somewhat similar effect to that of evaporation must result whenever heat is communicated from a hot surface to gas.

The particles which impinge on the surface will rebound with a greater velocity than that with which they approached, and consequently the effect of the blow must be greater than it would have been had the surface been of the same temperature as the gas.

And in the same way whenever heat is communicated from a gas to a surface the force on the surface will be less than it otherwise would be, for the particles will rebound with a less velocity than that at which they approach.

It is then shown mathematically, that for every English unit of heat communicated to steam at a temperature of 60 deg., the reaction on the surface is equivalent to 38 lbs. acting for one second; and in the same way for air the force is equivalent to 55 lbs. It is also pointed out that since the diffusion of heat within a gas is inversely proportional to its density, the amount of heat communicated from a surface to the surrounding gas is independent of the density of the gas, and hence, that the reaction on the pith in Mr. Crookes' experiments would remain constant as the vacuum improved, while the counteracting forces would diminish and leave the balls more free to move. It is therefore assumed that the results obtained in those experiments might have been at least in part due to such forces.

THE VENTILATION OF MONT CENIS TUNNEL—ITS APPLICATION TO HOOSAC TUNNEL.

By CHAS. P. HARRIS, C E.

Written for Van Nostrand's Magazine.

Through the ignorance or carelessness in treating this subject, misstatements have come into public prints that are calculated to give a false impression. From conversation with a French engineer and personal observation, a few facts have been obtained that may be of interest at this time, especially as the completion of the Hoosac Tunnel has given considerable importance to the subject generally, in this country.

Although, before the completion of Mont Cenis Tunnel artificial means were resorted to, in order to keep the air of sufficient purity from noxious gases and fumes of the explosives, since the work has been finished this has been found unnecessary.

It is well known that owing to the great height of the mountain over the tunnel line, a central shaft was impracticable, so the tunnel is largely dependent on the two portals or ends for the admission of air. There are other openings, however, that must be taken into consideration, as may be seen from the following diagram (Fig. 1):

I represents the opening near Bardonneche, on the Italian side. F shows the double exit at Malone the France end. Trains pass in and out at I and H, M being an opening on precipitous side, used as a dump during the construction. A few rods from the Italian terminus, at C, is a shaft, rising some fifty or hundred feet, to a short horizontal secondary tunnel at right angles to the line through which the rock was removed.

Fig. 1.

Between this and the portal are about six semi-circular arches, some 12 ft. in diameter, and only a few yards apart, which open out of the nearly-perpendicular side, at the bottom of the tunnel, to the free air. The shaft on the Italian side and the second portal at the France end, were indispensable in building the tunnel; but, together with the side arches, they form a very important consideration in the ventilation.

The marked difference in the tempera-

ture of the two ends serves to make a natural draft. So striking was this on the occasion of passing through it into France, that the change seemed as great as going from the sunshine into the chilling air of an icehouse.

Among the various methods of artificial ventilation for tunnels, it has been suggested to run trains of cars rapidly through to create a draft, but where this is accomplished by the natural features of the location, it is of course unnecessary to resort to any such increased expenditure.

Let us see the result of passing through the Mont Cenis Tunnel with the ordinary traffic of the road. The most unfavorable circumstances for quick ventilation would be in the case of a train running from the warmer into the colder atmosphere, or from Italy into France, as in this case the rapidity of the current of air would be slower than if the train was going in the direction of the wind, more retarded even than if the train was not in motion. The velocity of the air through the portal, shaft and side openings can be seen immediately after the entering of an engine, for out of each pour great volumes of smoke and steam. The cold air being more or less heated from this, the current is increased and the tunnel sooner freed from impure air. Should the temperature become more nearly equalized at the two ends, there would be a greater tendency for the smoke to become troublesome. But from experiments made at the time referred to, it is thought hardly possible that this will ever prove the least annoyance. One window and then both in the compartment were opened after entering the tunnel, and kept so through a short stop, and the remainder of the trip, all of which occupied about thirty minutes, and the air was not found in the least affected.

In discussing the effectiveness of natural ventilation at Hoosac Tunnel, it must be borne in mind that it is only about half as long as Mont Cenis—nearly $4\frac{3}{4}$ miles (25,031 ft.)—and that unlike the latter, there is a central shaft of considerable size rising near the centre to the surface of the mountain.

Glancing over the early reports of Hoosac Tunnel, written before the practical results of European tunnelling convinced us that long underground passages were feasible, the proper means of ventilation was considerably agitated. Among the plans proposed was the use of engines after its completion, throwing fresh air into the tunnel, thus driving out the impure gases, as is now done, the compressed air running the drills, and ventilating after it is freed.

By the slow progress of the work at the beginning, a central shaft after a few years was under way, thus giving two additional faces from which the work could be advanced. But this was not the only consideration that made the immense additional expense appear warranted to the people of Massachusetts. It was to act a very important part in the ventilation, doing away, many claimed, with artificial means after the tunnel was completed. The argument, in brief, was that the shaft would act as a chimney, making a draft that would take off the impure air, fresh air rushing in from the portals.

That this will not prove the actual result, is shown quite conclusively from a fact that has become known since joining the headings from the central shaft and east end. The observation that the flame of the miner's lamp, during certain hours in the day, indicated the current of air to be in one direction, and reversed at others, is apparently insignificant in itself, but it essentially solves the problem, as to the utility of the shaft in point of ventilation, showing, however, that the theory for a long time held, that the current of air would always have the same direction, is hardly probable.

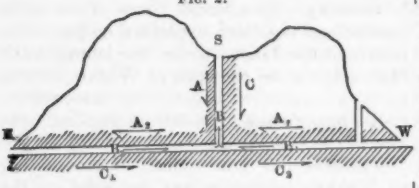
But it is not my purpose to treat of the correctness or incorrectness of certain suppositions. The question that is before us, and the one of most importance to railroad interests is, whether the natural ventilation of Hoosac Tunnel will satisfy the needs of the travelling public. From the results of investigation at both Mont Cenis and Hoosac Tunnels, there appears to be little doubt about it. Although the natural advantages of a cool French climate and the warmer atmosphere of Italy do not exist in the present case, the difference in temperature necessary to cause a draft is practically seen.

The current will not at all times be from end to end through the tunnel, but under certain circumstances passes up through the shaft. Referring to Fig. 2 will illustrate this more fully (the profile is drawn from memory, but is accurate enough for our purpose).

The temperature at the east end, E, being naturally higher in the forenoon than either at shaft, S, or west end, W, a draft

is created in direction shown by the arrows A, A_1, A_2; towards the middle of the day the warmer air at S gives a current shown by arrows B, B_1, B_2; the latter part of the day, just the reverse of what existed in the forenoon, can be seen, and the draft is in the direction of C, C_1, C_2. This is on the supposition that the temperature is not uniform at the three openings. Assuming that it sometimes is so, as is the case when the

FIG. 2.



sun does not materially affect the air, the shaft would act as a ventilator, carrying off the smoke, as represented by B, B_1, B_2, for in this case the atmosphere near the mouth of the shaft, being naturally warmer than the damp air below, rises and makes a current upward. These latter statements are made on no actual experiments by the writer, but are inferences believed to be warranted by reports from reliable authority, and have been practically demonstrated in part. In the observations at Mont Cenis Tunnel, the report was found to be incorrect that trains were not allowed to pass through within half an hour of each other. No sooner had one come out than another was seen entering, the second being a freight train with engine at each end; thus no hindrance to traffic was experienced on the ground of smoke. Whether this will be the case at Hoosac Tunnel, will soon be unquestionably answered.

As far as human foresight can tell, it would seem that an effective and satisfactory ventilation will result from natural causes, and no serious inconvenience be experienced by impure air during the few minutes' ride between the Deerfield and Hoosac valleys.

NOTE.—The writer, having placed the contents of this paper before an engineer several years engaged at Hoosac Tunnel, for perusal, previous to offering it to the press, was advised to have it published, the following brief comments from him, bearing on the subject, are appended:

"In the Hoosac Tunnel the currents of air seem to vary in accordance with the conditions that prevail in different seasons of the year. Whenever the outside temperature is lower than that of the tunnel, then the current always travels towards the coldest point. But whenever the outside temperature is higher than that of the tunnel, then the cold tunnel air seems to move down grade by the force of gravity, toward the warmer side, sometimes drawing the air of the central shaft, and the air of the cooler side after it. * * * *

"There is good reason to believe that there will be no trouble in regard to ventilation."

THE ANCIENT WORK OF THE COPPERSMITH.

From "The Builder."

The subject of the earliest artificers' work in copper, is one that possesses extreme interest, for many different reasons, and it is one as to which much further information than we actually possess is extremely desirable. The chief difficulty that attends the commencement of the inquiry is this. As a general rule, in art, the simpler processes are more ancient than the more complex. Now the production or the working of a metal of any description may naturally be supposed to be more ancient than that of any alloy of that metal. But our earliest relics of any cupreous arms, tools, or other objects, are not, as a rule, of pure copper, but some kind of bronze, or copper alloy. It is perfectly well known that certain alloys of copper are far more manageable by the workman, as well as harder and more available as tools or weapons, than is the pure metal. But we must regard it as probable that a considerable amount of skill had been attained in the smelting and casting of copper, before the ancient coppersmith thought of alloying the metal; and as utensils of bronze so far precede, in the archæological series, any evidence of the discovery and the manufacture of iron, the commencement of this early metallurgic work seems to be pushed back into an almost unattainable antiquity.

The best source of light which we may

now expect to gain on this point is the careful survey of the ancient world, including not only topographical information, but that accurate physical investigation which shall tell us of the source of the wealth of the future and of the traces of the industry of the past. Here archæological research joins hands with industrial inquiry. When we have ascertained, as we may properly hope to do, from what sources the various nations of antiquity, whose history we seek to trace, derived their metals, we shall have the first positive information as to the origin of the various descriptions of ancient bronze.

Copper occurs in a virgin or native state in many places, especially in outcrops. It also occurs in veins, and "pockets," or nodules, which the French miners call *géodes;* where it ramifies into crystals, and into delicate efflorescent threads. In Siberia is found the *cuivre oxydulé*, which resembles a dusky-red stone, sparkling with specks of metal. Black oxides, and blue and green carbonates, known as agarite and malachite, accompany native copper. Specimens of the former are found at Chessy, in France, of a lovely dark-blue, resembling, but darker than, that of the blue vases usually exhibited by chemists. Malachite occurs in the Oural mountains, and its use in Russia as an article of splendor is well known. The ordinary yellow *pyrites* is of frequent occurrence in Wales and elsewhere; and its little bright pyramids and parallelopipedons may readily be mistaken, by the unwary, for gold. The "peacock-copper" of Tuscany has iridescent colors. Like the yellow pyrites, it is a double sulphuret of copper and of iron. The Fahlerz, or grey copper, of the Germans, contains, besides copper and iron, silver, arsenic, and antimony. It is smelted for the sake of the silver and copper, but is extremely difficult to manage, from the complex nature of the ore. But it is highly probable that in this gray copper we have an indication of some of those deposits of natural alloys, which fact suggested to the ancient metallurgist the production of bronze.

Tin,—which, with copper, constitutes true bronze,—is stated in the works on metallurgy to be unknown as a mineralogical neighbor of the latter metal. It is not known to occur in a virgin state. The Cassiterides, or tin island of the ancients, whence this valuable metal was brought by the Phœnician navigators before the time of Homer, are as yet undetermined; though some authors have sought to identify them with our Cornish coasts. Tin is usually found as a crystallized oxide, of a chocolate-brown color, and a form closely resembling rock crystals. More rarely it occurs in what are called stanniferous sands, either yellow, rose-color, or translucent as crystal. It is found in India; supplies at present are derived from Banca and Malacca, as well as from Cornwall. It also occurs in Brittany. The island Vectis of the early navigators, has been explained to lie at the mouth of the Loire; to be the island Saint Michael; to be the Isle of Wight. From each new guess we come to the same result,—the importance of a better physical survey of the Old World.

There is little doubt that, on descending to historic times, tin was brought to the basin of the Mediterranean from India, from Gaul, and from Britain. The mineral was readily separated by washing, from the sand in which it was found, and then exposed to heat. As the ore is a compound of oxygen with tin, a charcoal fire will effect the reduction of the metal, so that the process has little varied, in principle, from the earliest date to the present time.

No ancient author speaks of bronze, the *æs*, or *cha'cos*, of the Classic writers, as if possessed of any acquaintance with its compound character. The hardening, tempering, and working of bronze is spoken of as we might now speak of the manufacture of iron. When not only the sword and the hunting-knife, but the chisel, the needle, the axe, and the fish-hook were made of bronze, there can be little doubt that the early craftsmen studied and experimented how best to give to their work the hardness of the flint, combined with the elasticity or tenacity of bone.

Very recent discovery has thrown a ray of light on this difficult subject of inquiry. And in the immediate vicinity of Sidon in Phœnicia, have been recovered not only copper mines, but a closely neighboring lode of stanniferous crystals. It is also stated that coal sufficient to carry on the operations of smelting is in the immediate neighborhood. A ridge of hills runs east and west in this part of Syria, terminating chiefly on the coast. Steps are in contemplation for the re opening of these ancient mines. But their discovery is more important as an archæological than as an industrial question. It tends to show that Nature herself

indicated the original mixture of bronze. The position of a source of this alloy in the very headquarters of the most famous mariners of antiquity is another most instructive fact. Hitherto it has been utterly inexplicable why the tin of Cornwall or of India should have been sought in order to mix with the copper of the Mediterranean shores. But when the alloy had once been indicated or casually found, by the smelting of contiguous ores, the search for the rarer metal would have been a natural result. Again, what occurs at Sidon may have occurred elsewhere, and the very earliest bronze may have been indicated by Nature herself.

Brass, which is an alloy of copper and zinc, is a much more modern alloy than bronze. We know but little of its existence before the imperial age of Rome. We find that new brass coins were struck by Julius Cæsar, which Pliny says contained *cadmia* from the Livian mine, and were equal to the excellence of *orichalcum*, for *sestertii* and *dupondii*. *Orichalcum* is sometimes spelt *aurichalcum*, as if it meant copper of a golden color; but its etymology really denotes "mountain copper," and some native alloy was probably first intended. *Cadmia* is taken to mean calamine, or zinc ore. Strabo speaks of a "false silver," which, mixed with copper, became *kramu*, or alloy, which some called *orichalcum*. Copper itself is said to have derived its name from the island of Cyprus; and brass, or rather the Greek word *chalcos*, from Chalcis, in Eubœa. The Corinthian brass, which is occasionally mentioned as of extreme value, is generally taken to be the same as *electrum*, or a mixture of gold and silver. Specimens of an argentiferous gold, rich in silver, from Transylvania, are to be seen in the British Museum, under the name of *electrum*, which attract attention from the sharpness of the crystalline forms. As the knowledge of metallurgy passed from a craft into a mystery, and especially when the expectation of being about to discover the secret of the transmutation of metals had seized the imaginations of men, tin was known by the sign of Jupiter, copper by that of Venus, gold and silver by those of the sun and the moon.

The specimens to be found in museums of ancient objects in bronze are numerous and important. We are not now referring to the statuettes and sculptural bronzes, among which may be found some of the most perfect specimens of ancient art anywhere extant. One of the latest additions to the bronze room of the British Museum is a female head, of unrivalled beauty, and also of great interest, as showing much of the method of the ancient workers in bronze. But we rather call attention to such undated specimens as the bronze Etruscan *krater*, found at Capua, with mounted amazons round the rim; and the draped female figure from Sessa, on the Volturno, a town famed for the rare beauty of its women,—one of the most ancient and interesting examples of casting in bronze.

Ancient bronze has not the indestructible character of the precious metals. The disinterment of a vase may, unless special care be taken for its preservation, lead to the rapid crumbling of the object into dust. At Baiæ, near Naples, is an ancient cemetery, in which the different orientation and structure of three super-imposed strata of tombs bear testimony to the successive occupation of the spot by three distinct races. The Oscan, or Etruscan tombs, in this cemetery, which are built of square stones, with a pyramidal roof, not unfrequently contain large bronze vases, of nearly globular form, which are found bedded in a layer of perhaps not more than 6 in. of consolidated dust. The late Count of Syracuse opened many of these tombs, and recovered many interesting objects; among others, the dressing-case of a lady, with implements in bronze. It was his Royal Highness's custom to have the bronze objects plunged into boiling water immediately on being unearthed, which was stated to be the only known precaution against speedy decay.

An extremely interesting question is as yet unsolved as to the method of coinage in use in ancient times, not for copper alone, but for gold and silver. The subject is intimately connected with that before us from the fact that the dies used in coining were exclusively of bronze or of copper. From the beauty and sharpness of many ancient coins it is evident, not only that the art of the die-sinker, as a matter of graceful taste, was of a very high order, but also that the metallurgic or mechanical part of his craft must have been adequately advanced. That means of hardening bronze, with which we are not now familiar, formerly existed, seems hardly to be questioned. But our most accomplished numismatists speak with no little

hesitation as to the process by which the impression of the die was communicated to the coin.

We are not, however, without some positive information on the subject, although more is still very desirable. The British Museum possesses among its numerous treasures an ancient Roman die. This is an iron implement, formed in two parts, one being a socket, into which the other fits. In the middle of the socket is a circular recess, into which a copper matrix is fitted. The plunger, or upper portion of the die, has a similar recess, fitted also with a copper die. The disc of metal to be struck must have been placed on the lower die, and the guidance of the socket served to bring the upper die into exact opposition to the lower. There is no collar in order to keep the coin central on the die. It is possible that a loose collar may have been lost, but the probability is, that the metal instrument is complete as it exists. The reason for this opinion is the great irregularity with which many ancient coins are struck. It is rare to find the impression central. A piece of unstamped metal is often found on one side, while the device overlaps the metal on the other. This irregularity would, however, have been very natural, if the disc were simply placed on the die by the workman, without any collar to confine it. In the recent improved process for striking coins and medals, a loose steel collar is added, which at once gives a central position to the device, secures the exact roundness of the coin, and serves to mill or ornament the edge. The process may be watched any day at the International Exhibition at South Kensington. It is to be lamented that the modelling of the large gilt medal, which has been recently issued by the directors of that institution to the exhibitors, does not equal the mechanical excellence of the machinery by which it is turned out.

The question remains, of the mode in which force was applied to the dies. The word "struck" is still employed, although it is, in fact, a gradually increasing pressure which is brought to bear on the disc. In the earliest coins it is very possible that a violent blow was actually given to the die. The square depression on the reverse of many ancient coins seems to point to this method of formation. But the British Museum die has not been so treated. It is made of excellent iron, more closely resembling that of Styria than any now commonly made, but which we believe to have been procured from the Apennines. But the plunger, or upper part of the instrument, has no marks such as a series of violent blows would have occasioned. Our readers who are accustomed to the blacksmiths' sets will understand what we mean.

We think the inference is unavoidable, that the iron must have been inserted in wooden blocks; and that pressure must have been applied as it is in the oil-presses and the maccaroni-presses of Italy, at the present day, by the combination of the lever and of the screw. The habits of the peasants and lower classes of the Peninsula, especially in the wilder parts, as in the Abruzzi and the Calabrias, are wonderfully little changed since the imperial times. At Canosa, for example, the very same grittiness in the bread which Horace deplores in his journey to Brundusium still endangers the teeth of the eater. The mode of applying enormous pressure which is now in use is, there can be little question, as ancient as it is effective. Rude in its details, it is essentially in principle one with the latest machinery of our mints.

The dies in the instrument which we are describing seem to be of copper, and bear marks of rough usage. But it can hardly be doubted that among the Greeks, and probably the Asiatic nations, hardened bronze was employed. Some of the vexed questions as to ancient coins hinge, to a great extent, on this subject of the hardness of the die. Thus when coins are found very closely resembling one another, but not *fac similes*, it is supposed that they are produced by different dies cut and used in the same year. This, of course, is possible, although it is also possible to ride such a hobby to death. Thus De Sauley figures, in his "Recherches sur la Numismatique Judaique," plates xiv. and xv., eight copper issars, or assarions, which differ very widely in their treatment of the palm-tree and the vine-leaf which they bear, in the arrangement, and even in the type or form of the letters on the field; and ascribes them all to the same year,—viz., 134 of the Christian era. This extraordinary attribution is only brought within the limits of possibility by the assumption of the use of numerous dies in the same year,—an assumption, however, that does not account for the artistic and paleo-

graphic differences of the pieces in question. It has been clearly shown by a writer in an important contemporary publication ("Bible Educator," parts xiv. and xv.), that the year II. on these coins refers to the second year of the seven, a constantly-recurring date, the distinction of which, on the coins used for sacred tribute, was important. Thus the absurdity of attributing 30 per cent. of all the known Jewish coins to at the outside 9 out of 184 years, will, it is to be hoped, not disfigure any further works on coinage.

The distribution of copper over the surface of the earth is wide and abundant. In the Old World it occurs in Asia Minor, Italy, Spain, France, Morocco, Algiers; as well as in Persia, Abyssinia, Congo, the Cape of Good Hope district, and Madagascar; and in England, Germany, Sweden, and Russia. It occurs on the shores of Lake Baikal, in China, and in Japan. It is found in Australia. In the New World it occurs in Canada, in the United States, in the Antilles, in California, and in Chili. It tinges the promontory of Cape Farewell. These are only the best known and more conspicuous deposits, as they appear on the face of the map. In Russia, copper mines were worked, in prehistoric times, in Siberia, in the Bashkir land, and in the Kirghis steppes, by a people of whom we have no account. Early in the present century the now famous mines of Nijni Tagil were commenced; and soon after it was discovered that the whole of the eastern slope of the Oural, from Voskresensk in the extreme north, to near the village of Malvatinea in the extreme south, abounded, more or less, in copper. Tin is also found in the Oural, though it is not now worked. The yield of the ore at Nijni Tagil, from 1814 to 1830, was above 3 to 4 per cent. In 1836 it rose to 5 per cent.; from which it has gradually dropped to half that proportion. The depth of the mines here is ninety fathoms. Near Simbeisk, in former times, it was found profitable to work a copper ore which contained only two per cent. of metal. Old clay pots have been found here, which were used by the early smelters, and which indicate from their great rudeness, a richer ore, as no results could be obtained from the present ore by so rude a process. At the fair at Nijni Tagil copper ore sold, in 1870, at from 2½ to 3 kopecks per pood, being equal to from 3s. 11d. to 4s. 8d. per ton; so that the copper is made for £47, 5s. per ton. The Oural mountains yield, besides copper and tin, gold, silver, lead, sulphur, chrome ore, diamonds, jasper, marble, talc, alabaster and steatite.

Spain was the great source of the supply of metals for the Romans, as well as for their rivals, the Carthagenians. Ancient mines have been discovered in the Spanish peninsula, some of which have been resumed with profit. Veins of copper and tin, as well as deposits of lead, of iron, and of antimony, await the industry of the Spaniard, whenever the good time shall arrive when Spaniards become industrious.

In the Alpine districts, Piedmont is rich in metalliferous strata. The Val d' Aosta is rich in copper pyrites, as the Val d' Anzasca is renowned for gold pyrites. The mountains which border the Gulf of Genoa are rich in copper. The hills of Modena, famous for their quarries of Carrara marble, contain copper, as well as iron, lead, and silver. On the north portion of Tuscany are found veins of argentiferous copper. From the mines of Campiglia the bronze of the ancient Etrurians is said to have been derived. In fact, the whole western slope of the Apennine chain, running to the south-east from the shore of the Gulf of Genoa, is rich in metalliferous strata. The silver which formed the materials for the famous coinage of Syracuse, was derived, it is thought, from the Calabrian Apennines.

From this hasty glance at the regions whence much of the metal used in the bronze period must have been derived, indications may be grasped which the advance of physical geography will convert into positive sources of knowledge. It would seem that copper, like gold, existed in a virgin state, and that the native lodes and the richer ores were successively exhausted, until the ore became too poor to repay the rude process of the ancient smelter. It also appears clear that, in certain places, as at Sidon and in the Oural, tin is even now found in close proximity to copper. In other places calamine, or zinc ore, is found near copper lodes. We infer that both bronze and brass were thus, in the first instance, the natural products of certain rich lodes or ores. As these, in the long lapse of time that preceded the use of iron, became exhausted, commerce, taught by metallurgy, sought the rarer metal, tin, in those spots whence it is now derived.

PROGRESS OF THE IRON AND STEEL INDUSTRIES.*

By DAVID FORBES, F.R.S., etc.

From the "Journal of the Iron and Steel Institute."

Annual make of Iron and Steel in the World.—In the third Quarterly Report for 1872, were produced from American sources an approximate estimate of the total production of cast iron on our globe during the year 1871, and now we present a similar one, compiled from the most reliable sources at our disposal, which will probably be found to be a still closer approximation to the truth :—

		Tons.
Great Britain	1873 ..	6,741,929
United States of America	1873 ..	2,695,000
Germany..	1871 ..	1,664,802
France	1873 ..	1,381,000
Belgium	1872 ..	652,565
Austria, with Hungary	1871 ..	424,606
Russia	1871 ..	354,000
Sweden	1872 ..	322,000
Luxembourg	1872 ..	300,000
Canada	— ..	100,000
Italy	1872 ..	73,709
Spain	1870 ..	54,007
Norway	— ..	20,000
South America	— ..	15,000
Japan	1871 ..	9,370
Switzerland	1872 ..	7,500
Asia	— ..	40,000
Africa	— ..	20,000
Australasia	— ..	10,000
Total	..	14,885,488

Wherever possible, the date of the last official returns is given in the above statement, which, as it stands, indicates that the present annual production of cast iron in the world amounts to at least 14,885,488 tons, as compared with 13,315,000 tons stated in the former estimate, 13,825,000 tons in the official report of the Vienna Exhibition, and 12,455,000 given in Wagner's Chemische Technologie, 1873.

Africa.—All accounts from Algeria concur in representing the development of the iron mines of this colony as becoming every day of more importance. The iron mine Ain-Mokhra, or Moktael-Hadid as it is more commonly called, is being worked most successfully, and has exceeded in its production the most sanguine hopes of its owners. Before the Franco-German war the output of iron ore from this mine had reached some 20 000 tons per month, and although during the war it declined greatly, it has now reached more than 30,000 tons per month, and at this moment some eight trains, each of 200 tons, or 1,600 tons in all, are sent per day down to the port of Bona.

Australia.—According to last accounts, the South Australian Steel and Iron Company has commenced operations at Mount Jagged, and some eight lodes of iron ore, containing between 50 and 60 per cent. of metallic iron, and from 30 to 40 feet across, are reported to have been discovered near Ballarat.

From Victoria accounts of new discoveries of valuable deposits of brown hematite and magnetic iron ores have been received, it being further stated that these are situated in close proximity to limestone, fire-clay, coal, and a railway station.

Austria.—Since the financial crisis of last year, the state of the iron trade of this country has been anything but satisfactory, and many new undertakings previously commenced, as among others, the great blast furnace establishment of Dr. Strausberg, have, it is reported, been stopped for the present, or abandoned. Excepting some smaller iron works scattered over other parts of the country, and the lesser iron districts of Moravia, Galicia, and Lower Hungary, which each produce something between 30,000 and 40,000 tons of pig iron per annum, the bulk of the Austrian iron manufacture is confined to the three great centres: Bohemia which turns out about 130,000 tons; Styria and Carinthia, producing some 178,000 tons; and upper Hungary, with a make of some 100,000 tons of pig iron yearly; of these three districts Bohemia is the only one provided with extensive coalfields, which, although at present comparatively but little developed, must soon assume much greater importance from the numerous railways which have lately been constructed, or are in course of construction, for placing them in communication with the iron ores and the rest of Austria. The Adalbert Huette at Kladno, recently visited by the author, contains six blast furnaces, with extensive foundries and rail, girder and bar rolling mills, which are stated to have turned out of late years some 35,000 tons of rails, girders, etc., per annum; at present, *i.e.*, in June, only one blast furnace is in operation,

*Abstract of the report to the Iron and Steel Institute.

and most of the mills are idle. A remarkable feature in these works is the carrying out on the large scale of Mr. Jacobi's (who is director of the establishment) process for dephosphorizing the iron ore previous to its being smelted in the blast furnaces, for a description of which we refer to the technical part of this report.

In Styria, the puddling of iron is almost altogether effected by the employment of brown coal or peat as fuel. The latter material is successfully used at many works, and when burnt in Siemens's regenerative puddling furnaces gives from nine to ten charges of 400 lbs. each, with a loss of 5 per cent. and a consumption of 16 cubic feet air-dried peat, whereas the quantity of peat required for puddling in an ordinary furnace is as much as 24 cubic feet per 100 lbs. of puddled bars.

Belgium.—The condition of the iron trade in this country has been most unsatisfactory to all concerned therewith; many blast furnaces have been kept idle, and most of the other works have been but barely paying their way, while the sale of Belgian pig iron has been much affected by the competition of the Luxembourg ironmasters, who have been selling in opposition at any prices obtainable. For some months past, owing to the strikes in England, the Belgian prices became so much lower than those here, that very considerable orders for girders, plates, and even rails were obtained in England, and Belgian iron of certain classes has been successfully competing with the local produce in the midland counties. It is worthy of remark, however, that, in spite of this competition, no less than 3,806 tons of English railway iron were exported to Belgium during the month of May, 1874, as compared with 1,166 tons in the same month 1873, and only 470 tons in May, 1872. The Belgian exports of iron to Ge many seem to be getting less and less.

The general feeling of the Belgian ironmasters is strongly in favor of a law being passed for the granting of concessions by the Government for all deposits of iron ores, which cannot be worked open cast, but can be explored by shafts or adit levels; the Minister of Public Works has been petitioned to this effect by the Association des Maitres de Forges, and the subject has also been taken into consideration by the Comité Métallurgique de Liège.

France.—From the Bulletin du Comité des Forges de France, No. 87, we extract the following statistical details of the production of iron in France during the last year:—

Production of Cast Iron in France during the year 1873.

	Foundry Pig	Forge Pig.	Total in Metrical Tons.
Total for 1873.	252,834	1,129,111	1,381,945
in 1872.	173,806	1,007,455	1,181,261
Increase in 1873.	79,028	121,656	200,584

The total production of pig iron in last year is thus seen to have attained the figure of 1,381,957 metrical tons; 200,695 tons in excess of the previous year's production, and only about 16,000 tons less than the production of 1869—1,398,000 tons—which was the greatest quantity of cast iron ever made in the course of one year in France. The manufacture of wrought iron in 1873 did not bear the same relations to that of 1872 and 1869 as was the case with the cast iron; for here we find the increase only to be 23,666 tons over 1872, while the difference between the figures of 1869 is still more marked, being some 126,000 tons less than the production of wrought iron in France during the year 1873.

With regard to steel, the production of steel of all kinds during 1873 attained the figure of 167,677 metrical tons, against 138,552 tons in 1872, or an increase of 29,124 tons, which shows that this manufacture still continues increasing at about the same rate as before, as will be seen from the following figures:—

1863,	total production was	1,856	metrical tons.
1864,	" "	6,750	"
1865,	" "	9,751	"
1866,	" "	10,790	"
1867,	" "	19,893	"
1868,	" "	42,601	"
1869,	" "	52,400	"
1870,	" "	90,000	"
1871,	" "	110,000	"
1872,	" "	138,552	"
1873,	" "	167,677	"

The quantity of steel of all kinds imported into France, during the year 1873, amounted to 6,658 metrical tons.

The following figures indicate in metrical tons the total amounts imported into France

during the years 1873 and 1872 respectively:—

			Decrease.	Increase.
Cast iron	125,996	129,805	3,809	—
Wrought iron and steel	54,882	43,676	—	11,206
Total ..	180,878	173,481	—	7,397

On the other hand the total quantity of cast and wrought iron, steel, and manufactured articles exported, are returned as follows:—

For 1874 at 272,924 metrical tons.
" 1873 " 259,160 "

Thus showing a diminution 13,764 metrical tons in last year's exportation, or about 5 per cent. on the whole amount.

The quantity of iron ores imported into France in 1873 shows an increase of 52,000 tons on that of the preceding year, this augmentation being due in the main to iron ores received from Belgium, Germany and Elbe, since the quantity of ore imported from Algeria has but slightly increased, and that from Spain has been less on account of the disturbances in that country.

According to the Bulletin du Comité des Forges de France, for February, 1874, the consumption of rails by the different lines throughout France amounted in 1873 to 199,359 metrical tons, of which 133,261¼ were iron, and 66,097 steel rails, which figures may again be subdivided into

124,717 tons	iron and	64,077 tons	steel rails made in France, and
8,543	"	2,000 tons	steel rails imported from abroad.
133,260	"	66,077 tons	steel rails,

in addition to which, 18,085 tons of iron and 35,781 tons of steel rails made in France were exported in 1873.

During the first four months of the present year, the importation of pig iron amounted to 35,041 tons, against 53,154 tons during the corresponding period of 1873, while that of wrought iron is given at 13,166 tons against 18,913 tons in the first four months of last year. The importation of steel in the same period was 2,429 tons, as compared with 1,995 tons in 1873. The exportation of cast and wrought iron and steel during the first four months of this year amounted to a total of 72,147 tons, against 75,132 tons exported from France during the corresponding period in 1873.

The above figures show a diminution of some three per cent. in the importation, and 4 per cent. in the exportation, during the first four months of this year, as compared with the corresponding period in 1873.

At the commencement of the year the state of the iron manufacture in France was extremely unsatisfactory, and but little better than in Belgium; many furnaces were out of blast, and in most districts there was but little sale for the products, and very few orders on the books. The iron works in the basin of the Loire were, however, an exception to this state of things, and with them prospects were not so discouraging. At the end of March the horizon appeared clearer, and the state of things became somewhat better, but still it was far from satisfactory. During all this time the Creuzot works, with their twelve blast furnaces, and about 15,500 hands employed in the works and mines seem to have been fully occupied, and much satisfaction was expressed at their having obtained an order for 10,500 tons of rails for Alsace and Lorraine in opposition to both English and German tenders, among the latter being those of Krupp and Bochum.

Much interest has been shown in the process of M. Euverte for making steel from inferior pig irons (which contain more phosphorus than can be dealt with in the Bessemer converter) by the employment of ferro-manganese, and a company has been formed in Paris with a capital of six million of francs, entitled La Société des Fers et Acieres par Alliages des Manganèse, the objects of which, as expressed in its prospectus, dated Paris, 21st March, 1874, are thus stated:—

1. The sale and manufacture of alloys of iron with manganese.

2. The application of such alloys to the production of soft metal.

3 The application of such alloys to the production of steel containing more or less phosphorus either by the Bessemer or Siemens-Martin process.

4. The establishment, partial or complete, of works for such manufacture.

Germany.—The total production of iron ores of all descriptions in the Prussian provinces in 1872 amounted to 3,671,367 metrical tons, valued at 11,389,240 Prussian thalers, or about £1,708,300 and

which gave employment to 32,229 workmen, besides 56,040 women and children.

The production of pig iron in the Prussian States, in 1872, exceeded that of any previous year, amounting (castings direct from the blast furnace included) to 1,457,-825 metrical tons, valued at between eight and nine millions of pounds sterling, and being an increase of 12.3 per cent. in quantity, or 60.5 per cent. in value, on the production of the preceding year, or, if compared with 1868, an increase of no less than 38.4 per cent. in quantity, or 121.6 per cent. in value. The augmentation in value, owing to the much higher prices which have ruled for pig iron of late years, is naturally greater in proportion than the increase in the quantity of pig iron made.

The production of the forges of the Prussian States in 1872 amounted to 852,-902 metrical tons, to which may be added 121,227 tons re-worked from blooms and scrap, etc., which is regarded as being an increase of more than 37 per cent. on the production of the previous year.

The statistics of manufactured iron show the produce to have been—

	1872.	1871.
From the forges using pig iron alone	774,132	723,892 tons.
From the mills using wrought scrap and blooms	120,399	134,121 "
Total	894,531	858,013 "

The figures of 1871 are, however, considered as too high and not to be relied upon as in the case of 1872. The details of the iron manufactured from pig direct in 1872 are given as follows :—

	Metrical Tons.
Rails and fish plates	197,938
Railway axles and wheels	12 028
Profile iron for building, etc.	68 665
Heavy plates, etc.	23,324
Other undescribed iron	323,432
Plate and sheet	81,809
Tin plate	2,372
Iron wire	74,527
Drawn pipes	35
Total	784,130

According to the official statistics, the manufacture of steel of all kinds in the Prussian provinces employed 21,531 workmen, distributed in 58 steel works, and resulted in the production of

	Metrical tons.	Valued at about
Crude Steel	113,149	£1,945,350
Cast Steel	174,755	2,772,327
Total in 1872	287,904	4,717,677
as compared with 1871	235,175	4,074,072
also an increase in 1872 of	52,729	643,605

but as the classification adopted for the different varieties of steel was different in 1872 from what it was in 1871, so that, for example, much of what was entered as cast steel in 1872 is to be found under the heading crude steel in 1871, any comparison between the details of the production in these respective years is useless; but the quantity of steel manufactured in the Prussian provinces in 1872 is given below, with the explanation that under the name of crude steel it appears to be understood all steel made by the hearth, puddling, cementation or Bessemer processes, while the term cast steel (notwithstanding that Bessemer steel is certainly entitled to that appellation) seems to be confined to such as is made by the Siemens-Martin and crucible processes.

Production in 1872. Province.	Crude Steel. Metrical Tons.	Cast Steel. Metrical Tons.
Brandenburg	—	302
Silesia	4,553	—
Saxony	331	—
Hanover	14	15,334
Westphalia	50,318	79,879
Hesse Nassau	703	—
Rhenish Prussia	57.526	79,239
Total	113,445	174,754

while the actual return of manufactured steel of all kinds for 1872 is given as follows :—

Rail and Fish plates	149.010
Railway axles and wheels	65,302
Heavy plates and parts of machines	6,778
Cannons and Balls	6.592
Other Steel Articles	42,766
Sheet Steel	2,904
Steel Wire	250
Total	273,602

From the following figures, the proportion which the steel manufacture in Prussia

bears to that of the entire German Empire, and the wonderfully rapid rate at which this industry has increased during the last ten years, can be seen at a glance:—

	German Empire.	Prussia.
	Tons.	Tons.
1862	40,916	40,160
1863	54,250	53,254
1864	71,359	70,409
1865	99,543	98,209
1866	114,433	113,603
1867	122,591	122,148
1868	122,836	122,358
1869	161,719	149,366
1870	169,951	157,961
1871	254,514	235,176
1872	?	287,905

Greece.—According to official reports from Syra, a considerable quantity of iron ore has been exported by the Hellenic Metallurgic and Mining Company from the Island of Seriphos to England. It seems that the first shipment was made in 1872, and up to the end of October, 1873, seven steamers had carried some 8,000 tons of the ore to Newcastle, where it is reported to have been successfully smelted with a yield of 64 per cent. pig iron in the blast furnaces of the Royal Greek Iron Works near that town, which were alluded to in one of our former reports. The quality of the Seriphos ores is said to be equal to that of the best Spanish or Swedish iron ores, and a consignment of some 500 to 600 tons has been shipped from Seriphos to Koumi, in order to make an experiment in smelting it with the coal found at that place.

India.—During the six months ending September 30th, 1873, 5,690 cwts. of cast iron were imported into India, as compared with 3,819 cwts. during the corresponding period of the preceding year, and 7,203 cwts. during that of 1871, the whole of which, with the exception of 90 tons, was received from England. Of cast steel, 2,854 were imported, as against 10,709 cwts., and 18,379 cwts. in 1872 and 1871 respectively. In October last year, the importations of cast iron were 1,800 cwts., as compared with 330 cwts. last year, and 1,100 cwts. in 1871; while of steel 1,766 cwts. were imported, as against 1,583 cwts. in 1872, and 765 cwts. in 1871.

In the Records of the Geological Survey of India, will be found a communication by Mr. Theodore Hughes, entitled "Note on some of the iron deposits of Chanda, Central Provinces," which gives a description of some of the deposits of iron ore long worked by the natives in that district, as well as some details of the primitive mode of smelting still carried on at present in this part of the world, from which we venture to make a few excerpts as interesting, if only by showing how vastly different the scale is on which the manufacture of iron is conducted in different parts of the British Empire in the nineteenth century.

The native furnaces of Chándá are somewhat higher and larger than those of Bengal, being nearly 6 ft. in height, owing to the front face being carried upwards in order to back the ore around the feed hole. The height of the actual smelting shaft is from 4 ft. 6 in. to 5 ft., and its internal section that of a cone diminishing in diameter from 18 in. at a height of 6 in. above the hearth, to 9 in. at the height of 3 ft. above it. The hearth, as is usual, slopes from behind forwards, and the bloom is taken out through the face. The tuyeres are 9 in. long, $1\frac{1}{2}$ in in diameter behind, and $\frac{3}{4}$ in. in front, and they are supplied by bellows usually worked by hand.

The iron thus obtained is called "kit" by the Maharattas, and is a mass of spongy iron slag and charcoal, which has to undergo two refinings before it is considered proper malleable iron. The first of these operations is effected by the men who reduce it from the ore. They heat it in a refinery until the slag is more or less expelled, and the iron consolidated to a compact bloom, during which operation it loses so much in weight that a mass formerly weighing some 14 seers, will be diminished to 10 seers; the charcoal employed being, it is said, some 20 seers, or a little less. These blooms are then cut nearly in halves, when they are called "chúl," and sold to the regular metal workers (lohars), who work them over again, by which from one-third up to even one-half the weight is lost, and then it is made into the various agricultural or household articles in general use.

Taking the mean of the Múhl figures, it appears that:—

(*a*) $17\frac{1}{2}$ seers of crude iron are produced from smelting 63 seers of ore with 87 seers of charcoal.

(*b*) In the first refining, 20 seers of

charcoal are used, and the iron loses 5 seers in weight, thus reducing it to 12½ seers.

(*c*) In the final refining, about 10 seers of charcoal are consumed, and the result is from 7 to 8 seers of clean workable iron.

Thus, according to Mr. Hughes, 8 seers of malleable iron require for their production 63 seers of ore, and 117 of charcoal, which, reduced to English weights, are equivalent to 8 tons of ore, and 14½ tons of charcoal to the ton of wrought iron.

Italy.—The total quantity of iron ore exported from the Island of Elba, in 1872, amounted to 114,936 metrical tons, of which 53,023 tons went to France, 29,045 tons to England, and 32,868 tons to the mainland of Italy.

The company to which three of the principal mines at Rio were made over in 1851, for thirty years, by the Grand Ducal Government of Tuscany, as a guarantee for a loan of 10 millions of francs to that government, has signed an agreement with a French metallurgical syndicate, to supply 140,000 tons iron ore per annum for a period of eight years, dating from the 30th June, 1873, or in other words, for the remainder of the original lease—and have also made a mutual agreement with M. Brioschi, that they shall not send ore into the English or French markets, unless by special accord. A contract had previously been made by M. Sella, in the name of the Italian Government, with M. Brioschi, by which the two other iron mines of Calamita and Terranera, situated near the Port of Rio, are ceded to that gentleman for working up to the 30th June, 1881, and after that date, of the whole of the iron mines of Rio, for the term of thirty years, obliging him on his part to construct, within three years, a railway from the mines to the port, the necessary stations and piers for loading and discharging the ore, and ironworks capable of producing 35,000 tons pig iron or steel per annum, he being allowed to export iron ores to England in order to lighten the price of the coke necessary for smelting the iron ores, by providing return freights for the ships employed in its carriage.

Japan.—According to the official report of the Vienna Exhibition, the production of iron in Japan, during the year 1871, amounted to 9,370 tons. From San Francisco, in California, we learn that the Pacific Iron Works are now engaged in constructing machinery for smelting and rolling iron in Japan, which consists of steam engines with boilers, blowing machinery, ore crusher, ironwork for furnaces, bloom squeezer, steam hammer, shears, etc. The ore deposits, which are said to be extensive, are reported to be native magnetic oxides containing from 60 to 65 per cent. metallic iron, and of excellent quality. The machinery, in the first instance, will be shipped to Yokohama, whence it will be reshipped to the district in which the mines are situated.

Luxembourg.—The production of cast iron in the Grand Duchy has immensely increased of late, as will be seen from the following figures:

	Metrical Tons.
Make of pig iron in 1865	55,000
" " 1868	115,000
" " 1870	150,000
" " 1872	300,000

The extremely large stock of pig iron held by the Luxembourg ironmasters during the first half of the present year, and the evident determination they have shown of selling it at any price, has been seriously affecting the Belgian markets of late.

New Zealand.—The last news from this colony states that a company, entitled the New Plymouth Iron Sand Company, has been formed, and that its representative, Mr. Parris, had fixed upon a site for the erection of a furnace, and had concluded negociations with the natives for the purchase of the land required for the operations of the company.

A company, entitled the Parra Parra Iron and Coal Company, is being formed in Melbourne, for working an iron mine in the province of Nelson and the Collingwood Colliery adjacent thereto. Some of the ore has been smelted by Messrs. Drysdale and Frazer, and yielded over 40 per cent. metallic iron; and in a late number of the "Melbourne Argus," we find the following paragraph, relating to the prospects of the establishment of ironworks in New Zealand; which we reproduce verbatim, without making any comments on the correctness of the statement contained in it:—

"We learn that a company is in course of being formed in Melbourne, for the purpose of utilizing the discoveries of iron lately made in the province of Nelson, in New Zealand, on the shores of Massacre Bay. A prospectus has been issued, from which we gather that the ore is of extraordinary

richness, and the iron produced of the most superior quality.

Russia.—The Russian Government are endeavoring to encourage the development of the manufacture of iron in the country, by making, in their contracts for railway materials, the obligation on the contractors that these must be entirely of Russian manufacture. The iron trade in the Ural districts is described as being at present in a very prosperous condition, the prices being good, and the demand, more especially for Siberia and Central Asia, great and rapidly increasing.

M. Inostrantsev, who was, in 1873, engaged in a geological examination of the province of Olonetz, has reported the occurrence of immense deposits of coal and iron ore, and the council of that province has decided to apply to the Imperial Government for permission to open up and work these mines, which it is expected will be granted.

Spain.—At the Vienna Exhibition, the Compania de Minas et Hierros del Pedroso, near Seville, was awarded one of the medals of merit, for the iron ores and products of its furnaces and forges. This company possesses immense deposits of magnetic and specular iron ores of the finest quality, but owing to the increasing scarcity of charcoal, is not able to keep more than one of its three blast furnaces in steady work. The forges are provided with Siemens's regenerative puddling and reheating furnaces, and trains of rolls driven by water power; and now that the works will be immediately placed in communication both with the coal basins of Villeneuva and its own iron mines, by the railway nearly completed, the company will be in a position to work on a scale commensurate with the extent and richness of the iron mines.

In the Vienna Exhibition attention was also directed to samples of the iron ores exhibited by Sr. Hysern, from the mine of Calataunas, in the province of Granada, not more than some 15 miles from a harbor, the ore being, it is stated, visible on the surface for a distance of nearly two miles, and more than 600 feet in width. Its analysis shows 64.2 per cent. metallic iron, with 7.47 per cent manganese, but no phosphorus, and only 0.057 per cent of sulphur.

Sweden.—We have not as yet received the official statistics of the iron trade of this country for 1872, but we understand that the quantity of cast iron produced in 1872 amounted to 322,000 tons, as compared with 292,850 tons in 1871, and that of wrought iron to 193,000 tons against 183,989 tons in the preceding year.

The following analyses of Swedish iron ores are published by Mr. J. F. Lundberg, in Jern Kontorets Annaler for 1873, p. 320 and 321.

	A.	B.
Protoxide of Iron	81 05	82.62
" Manganese	0 15	trace.
Silica	14 20	12 21
Alumina	3.31	3.18
Lime	0 98	0.67
Magnesia	0.47	0.45
Total	100.16	99.13

A. Magnetic oxide of iron from Femmand mine in South Graengesberget, which contains 63.83 per cent. metallic iron.

B. Iron ore from Svederna Mines, in the province of Kalmar, contains 64.27 per cent metallic iron.

Tasmania.—Letters received from Tasmania give some information as to the proceedings of two recently-formed companies engaged in working the rich deposits of iron ore found near the river Tamar, on the north side of the island. With respect to the Charcoal Company, a tramway of some 4½ miles from the jetty on the riverside reaches the works, where an experimental furnace has been erected on a new patented system, some few hundred yards from the deposit of iron ore called the Hill of Vulcan, which appears from the accounts to be an enormous mass of red hematite and magnetic oxide of iron, free from sulphur, and containing some 60 per cent. of metallic iron. There are dense forests in the immediate neighborhood. Other deposits of iron ore also occur on the company's property, which extends over 450 acres of land.

Turkey.—As regards the development of the iron and steel manufactures of this country, we have not been able to obtain any definite information, and the state of these industries, as represented at the Vienna Exhibition, did not appear to be much more advanced than at the Paris Exhibition of 1867.

Among the most important ironworks appear to be those at Samakow, in the Balkans, which contain some twelve blast

furnaces, and turn out annually about 12,000 tons of wrought iron of excellent quality. The works at Routcha also produce about 5,000 tons of pig iron, and the ironworks of Klissoura, Palanka, and Rocka, whose production is not given, are supplied with iron ore from the mines of native oxide, situated in the valley of Novada and Klissoura—mines of hydrated oxide of iron are worked at Karatova.

THE STORAGE OF WATER.

By J. BAILEY DENTON, C.E., F.G.S.

The Amount of Rain Falling on the Surface of England and Wales.

The area of England and Wales is 37,324,883 acres, and the mean annual quantity of rain falling on an average of years on this surface may be taken at 32 in. Dalton, fifty years back, estimated the average annual rainfall of these portions of the United Kingdom at 30 in.; and, in the absence of actual records sufficiently numerous and evenly distributed to be relied upon, this estimate was a remarkably sound one. Since then, great efforts have been made to supply this deficiency, and thanks to Mr. Symons, we are now in a position to state with some degree of certainty as to the quantity of rain falling on the surfaces of the numerous districts characterizing the country, and have been enabled, by the information he has collected, to arrive at the maxima, minima, and means of those several districts, and then to strike the averages of years. Mr. Symons tells me that he considers the average mean rainfall of England and Wales to be 32 inches, and, having carefully examined the returns published by various authorities, I have been enabled to confirm, and therefore adopt his estimate.

It may be interesting to show how this quantity is arrived at. Dividing England and Wales by the outcrop of the Lias formation which runs from Whitby and Redcar in Yorkshire on the north, to Lyme Regis in Dorsetshire on the south, in a tortuous but nearly unbroken line, I find the mean of all recorded averages on the east of that line to be nearly 26 in., the extreme being 20 in. in parts of Essex (minimum), and 36 in. in a part of Sussex (maximum). This division contains rather less than 16,000,000 of acres. On the west of the Lias the average rainfall is 38 in., the extremes being less than 30 in. in parts of Gloucestershire and Shropshire (minimum), and upwards of 60 in. in parts of Wales, and 80 in. in the Lake district (maximum). This division contains about twenty-one and a-half millions of acres, and in it are included the Devonian hills of the Southwest of England, the silurian range of hills of Wales, and the carboniferous limestone hills of the north, which together form the Alpine range, and rise above the new and old red sandstone formations and the coal measures. The first described division consists of surfaces of which about two-thirds are porous. They form the outcrop of the water-bearing strata known as the chalk, the greensand, and the oolite; the remaining third being comparatively impervious clay soils, which resist more or less infiltration of the rainfall. The heights of this division above sea level will vary from 10 ft. in Lincolnshire to upwards of 700 ft. in the Downs of Sussex, Hants, and Wilts, with a large proportion exceeding 200 ft. The other division presents a much smaller proportion of absorbent surface, the principal formation of that character being the new red sandstone, which, though forming in itself a wide area, really presents but a small proportion of the whole. The remainder of the division consists, as already stated, of the Primitive, Transition and Early Secondary Rocks, which for the most part are covered but thinly with detritus of those rocks and vegetable matter. The height varies from a few feet to upwards of 4000 ft., with a considerable proportion more than 400 feet above sea level.

Deferring for a time an explanation of how these physical conditions affect the question of water storage, I should point out that every inch of rain falling on an acre of space supplies 22,622 gallons of water. Now if we first multiply this number of gallons by 32, the number of inches representing the average rainfall, and then the total obtained by the number of acres forming the area of England and Wales, we arrive at the immense total of 27,019,632 millions of gallons as the quantity of

water which on an average of years falls on the surface at the feet of the population, exclusive of the deposition of dew, which forms no very small nor unimportant item in the water economy of the country. Though the figures I have just given are, from their number, difficult to appreciate, it is most desirable we should comprehend their full magnitude at a period in our social condition when we are compelled, by the rapid increase of population, to secure a full supply of water as an essential to the public health, and when we are obliged, by the equally rapid strides of trade and commerce, to look forward to the time when the supply of coal may be exhausted, or its price advanced to a famine rate, in consequence, in a great measure, of our neglect of that element—water—with which Providence has furnished us, and which has ever been at hand as a natural and inexpensive source of motive power.

The Quantity of Water required for all Purposes.

The quantity of water required in our sanitary arrangements and for domestic and trade purposes amounts to a very small proportion of the large quantity of water which I have just given. The quantity of water actually consumed at present varies from as little as two gallons per head per diem in villages and isolated places where the water used is obtained by personal labor, to from 30 to 50 gallons per head per diem in some of our cities and towns where public supplies and considerable waste exist. The average quantity used throughout England and Wales for *all* purposes is probably not much more than 15 gallons per head, though it may be well to allow that before the next 20 years have passed the increasing demand for water for all purposes will raise this quantity to a mean of 25 gallons. Now, if the population of England and Wales, which reaches 25 millions, is multiplied by 25, it will amount to 625 millions of gallons per diem, or 228,125 millions per annum. To this requirement of the population we must add the water which is wanted by animals and farm stock scattered throughout the country, and which are not provided for in the water supply of towns. The number of horses, cattle, sheep, pigs and dogs does not much, if at all, exceed 50 millions, and if we consider that on an average each animal uses and wastes 5 gallons per diem, the total result will be 250 millions of gallons per diem, or considerably less than half the quantity required by the population. This quantity has to be supplemented by the water consumed in the production of steam used in manufacture as well as that which is used at the homestead or in the field, and which I hope will be greatly increased. This, however, even if we allow that steam-power to the extent of from 10,000 to 12,000 horse-power per annum is added to the power used in agriculture alone, cannot bring the whole to more than 1,000 millions of gallons per diem, or 365,000 millions per annum, which is only a 74th part of the total rainfall with which Providence blesses us on the average of years. In fact, if it were in the power of man to secure the whole of the water required for all uses before the rain was absorbed by the ground, the quantity would be comparatively so small that it could not possibly injuriously interfere with any of those functions which the rain performs, nor in any way affect our general water economy. To make this more clear it may be stated that if there were allotted to each unit of the population 25 gallons of water daily for all purposes, public and private, it would require 9,125 gallons for the year's supply, while one inch of rain falling on an acre of surface, being equal to 22,622 gallons, would afford a year's supply to nearly two and a-half persons.

I have taken pains to set forth these figures, and I lay stress upon them, because they cannot fail to show that, with such a quantity of water at our disposal, it savors of the ridiculous, if not of ingratitude, to complain at one time of scarcity of water for domestic, sanitary and trade purposes, and at another of the extreme wetness of the season. We have only to adopt as a nation the common prudence of household life, of collecting and husbanding our resources, to insure plenty at all times; for, although means and averages do not form with engineers the usual data for water supply, it is quite within the power of man to equalize quantities for his own use by storing excess to compensate for scarcity. We have it in our power, in fact, to provide for every possible want connected with human and animal life, and to become independent of dry years; the only thing required being sufficient reservoir space to provide against a succession of two, or possibly three dry years, when we may have

to deal with minima which may be taken to represent a third less than the quantities we have recorded as averages. Few persons realize, or are prepared to acknowledge, in times of drought, when the poor are paying a penny or two pence a pailful for the first necessary of life, and when cattle are dying in our fields of thirst, that they have by their own neglect thrown aside the most plentiful gift of Providence. They are, on the contrary, disposed to imitate the countryman of the fable who, when the wheels of his wagon stuck deep in the clay, called on Hercules for help instead of putting his shoulder to the work of withdrawal. That which takes place in the water-bearing strata of the earth in the way of storage of the winter's rain for the supply of springs and wells in summer, and that which takes place in the dew-ponds on the high downs of the chalk and oolite in the way of storage of dew as it is deposited from the atmosphere in the warmest weather of summer, are examples we ought to copy.

Yet it is remarkable how years roll past without an effort in this respect; and it is only now because we are suffering from a severe drought, extending more or less to the whole country, and there is a dread of a want of coal, that there is any chance of gaining attention. It is thirty years since I wrote the following words in an article on the "Drainage of Land and the Distribution of Water," in the "Westminster Review," vol. xxxviii., 1842: "Does not Nature, by the machinery of her rivers, her brooks, her springs, point out to art the means of increasing the general salubrity of our island, by providing an outlet for those floods which are peculiar to Britain from its diversity of surface, the prevalence of heavy soils in the valleys, and its sea-bound circumference? The evaporation of water, in the first instance, from the surface of the ocean, and its fall to the land in the form of rain and dew; its re-absorption by the atmosphere; its use by all animal and vegetable bodies; its descent into the porous strata of the earth to be discharged again in the form of springs to the sea, exhibit to man a vast system of perpetual circulation which should incite his emulation to become an instrument for the removal of obstacles which it would appear exist only that his energy may be roused into action." Within the last thirty years agriculture has, perhaps, made greater progress than any other branch of British industry, but nothing, literally nothing, has been done towards the conversion of the evil of excessive wetness into a benefit by provision against scarcity.

Distribution and Present Disposal of the Rainfall.

Having given the large figures I have stated as representing the quantity of rain which reaches the surface, it may be well to trace shortly how Nature disposes of it as it falls. All rain is either absorbed by permeable surfaces, or it is discharged directly by overflow from impermeable surfaces into the rivers, and by the rivers into the sea. In the one case it may be a mistake to speak of its entire absorption by permeable surfaces, for a small proportion is appropriated by vegetation before it is absorbed, and the rest when absorbed descends to the level of the water in the water-bearing strata as soon as supersaturation takes place, to reissue from the surface at the outcrop in the shape of springs, or to raise the subterranean water-bed in the earth. The water upheld in the soil by attraction is gradually given off at the surface by evaporation, and is replaced from beneath as long as the supply lasts. The water-level in these water-bearing strata is thus lowered by the outflow of the springs, and by evaporation. In the other case, the rain being wholly resisted where impervious surface exist, and partially so where those surfaces are only thinly covered with soil, passes off without much reduction, the only loss being that proportion which is directly seized by surface vegetation and evaporation. In the six months forming the winter half of the year, from October to March inclusive, floods are more frequent in proportion to the rainfall than in summer, in consequence of the absence, or dormant condition of vegetation, and the reduced extent of evaporation, and owing to the fact that the soil itself is frequently in a wet condition. During this period a considerable proportion of the rain having entered and saturated the permeable soils descends into the earth to do its work of replenishment. In the six months forming the summer half of the year, from April to September exclusive, on the other hand, floods are comparatively few, though they are injurious when they occur, and the quantity of rain penetrating the earth beyond a depth of 3 feet is very small. In-

deed, the water-bearing strata generally receive no appreciable replenishment during the summer; they are nearly wholly dependent for their replenishment on the supersaturation of winter. In some of the extremely open beds, it is true, such as the chalk, the new red sandstone, and the Bagshot sand, the infiltration of the rainfall is rapid, and a heavy rainfall will serve to raise the water-level even in summer, and set the lower springs running, but this is the exception, and not the rule. In fact, the storage of water in the earth does not accumulate until the winter rains have produced supersaturation. In a well that I carefully watched during the wet winter of 1872–73, I found the water stood on the 1st of January, 1873, at exactly the same height as on the first of the preceding July; while from the beginning of the year 1873 to the 1st of the following May, the water had gradually risen 7 feet 10 inches higher than it was on the 1st of January. A wet summer has very little effect in increasing the subterranean supply, but it has the advantage of restoring the water upheld by attraction, and thereby of lessening the demand on the water stored beneath, which would otherwise rise and lower the level of its bed. When great rainfalls occur in summer, that proportion which is not absorbed passes into the rivers to swell and increase their volume without any apparent corresponding advantage beyond raising for a short time their perennial flow. It may be stated that the proportion of rain required to maintain the natural flow of our rivers during the summer and dry weather periods of the year is about one-eighth of the average mean rainfall, or 4 inches over the whole of the river watersheds. Of course, in different rivers this will vary according to the amount of rainfall, the inclination of the surface, and the character of the soil. The quantity or proportion of rain which finds its way over the surface to be discharged by the rivers to the sea without entering the ground at all, taking the west and east side together, is at least 15 inches, or nearly four times the perennial flow, and nearly half the average mean rainfall. This quantity will necessarily also vary very considerably, according to the depth of rain and the character of the contributing surfaces. In the eastern and midland parts of England the mean depth of water run off in the shape of floods and freshets will barely reach 6 inches, while in the west, including the higher lands of the eastern counties of Wales, the Lake district and the northern counties, the mean may be stated to be 20 inches. Mr. Bateman showed in his evidence before the Metropolitan Water Supply Commission that it exceeded 40 out of 60 inches in the high grounds of Wales, while Messrs. Hemans and Hassard considered that it reached 65 out of 80 inches in the Lake district. I may mention, as an illustration of how remarkably quickly the rainfall is discharged, that although 44 inches of rain had fallen in the Lake district between the 1st of October, 1872, and the end of January, 1873, I found when at Kendal on the 19th of February (1873) the water of the Kent to be remarkably low, and was informed by the borough surveyor that it was 14 inches below ordinary summer level, and when crossing Windermere lake the day previous (18th Feb., 1873) the ferryman assured me that the height of the water approximated ordinary summer level. The present condition of drought (July, 1874) prevalent throughout the whole country, is as much felt in the Lake district as in any other; and I may mention as a contrast to the 44 inches which fell between 1st October, 1872, and 31st January, 1873, that 17¾ inches of rain only fell in the same period ending January, 1874.

It will be remembered that in the winter of 1872–3 the rainfall so far exceeded the average that it was thought wise to offer up prayers in our churches for drier weather. In the winter last past the rainfall has been very considerably *below* the average, though not so much less as in the previous winter it had been *above* the average. In the eastern counties—the driest part of the country—for instance, the quantity of rain that fell in the six winter months from October, 1872, to March, 1873, inclusive, was 21½ inches, while the amount due to the same period last winter, 1873-4, only reached 9 inches. The mean of many years is somewhat above 13 inches.

Comparing this mean with the rainfalls of the last six winters (in the eastern counties) we shall see that, although we have had within that period two singularly dry years, the fall of this last winter was less than any.

	1867–8.	1868–9.	1869–70.	1870–1.	1871–2.	1872–3.	1873–4.
Rainfall—October to March inclusive.....	12.90	18.00	15.12	15.35	13.25	21.55	9.

In order that the quantity of water discharged on an average of years from several different descriptions of gathering grounds may be appreciated, I will give from the late Mr. Beardmore's evidence before the Water Supply Commission, 1867, the outflow of the Lea and the Thames on the east of the Lias, and from some other authorities the discharges from river areas on the older geological formations.

River Basin.	Drainage Area.	Rainfall.	Discharge.	Year.	Authority.
	Sq. Miles.	Inches.	Inches.	Average.	
England—East of Lias:					
Thames	3,670	26.08	7.83	1850 to 1868.	Mr. N. Beardmore.
Lea	444	25.60	6.54	Ditto.	Ditto.
England—West of Lias:					
Rivington Pike	16½	45.70	35.50	1850 to 1867.	Water Supply Commission.
Mersey and Ribble	2,207	39.00	20.00	Average.	Rivers Pollution Commission.
Scotland:					
Loch Katrine	71	103 30	81 70	1854.	Beardmore's Hydrology.
Loch Lubnaig	70	66 70	50 96	1847.	Ditto.
Greenock	8	60.00	41.00	1827-8.	Ditto.

Storm or Surplus Waters to be Stored.

It is the surplus, or waste waters, which I compute at a mean of 15 inches, or rather so much of it as is not already appropriated, that may be stored with advantage. The quantity already appropriated is comparatively small; and though several large towns have been supplied by this means, the quantity so appropriated in those localities is fully compensated by the water of underdrainage discharged elsewhere, consisting for the most part of rain which, before drainage, had been upheld in the soil until it was evaporated. By many persons it has been supposed that the effect of underdrainage has been to diminish the water supply rather than increase it—I presume on the supposition that the springs would be weakened by the loss of that proportion of the rain which would be upheld in the 3 or 4 feet of surface soil which alone is affected by drainage. A little reflection will, however, satisfy every one that this cannot be the case, inasmuch as water cannot run out of the drains until the subsoil is filled with water up to the level of the drains, and the soil between the drains and the surface is in a state of supersaturation. When, in winter, this condition has been reached, a large proportion of the rainfall is discharged from the underdrains within 24 hours of its reaching the surface, if the surface soil be properly cultivated and rendered absorbent. In the summer there is little or no dischage from the underdrains of clay lands, though in many instances a never ceasing and copious discharge is obtained from the draining of surcharged free soils. There is no doubt that with extension of under-drainage an improvement of our rivers and watercourses has necessarily been effected, and that the water from the underdrains, when discharged, as well as that which overflows the surface, is carried down into the valleys with greater rapidi y than before. The result is a considerable increase in the aggregate, though, for the most part, the quantity obtained is due to the winter's discharge and not to that of the summer. Few would suppose that the quantity of land already drained, which is assumed to be three millions of acres, would furnish an effluent water equal in quantity to nearly half the water supply required by the whole population of England and Wales, for domestic, trade and public purposes. It is nevertheless true, inasmuch as the discharged water amounts to a mean of 150,000 millions of gallons on an average of years. The practical value of this fact will be acknowledged when it is understood that even in dry years the under-drainage water from an acre of land will be sufficient to supply four persons all the year round with 25 gallons each per diem.

At present we are content to draw the water out of the land, and instead of turning it to account, allow it to increase the evil of surface floods by its discharge into the valleys at times when they may be under water; and this we are doing when water has an increasing value as a source of motive power in consequence of the advancing price of coal. Allowing the new water of under-drainage to compensate for that proportion of the surface water that is already utilized, it may be assumed with

certainty that there are at least 20 millions of acres out of the 37,324,883 acres, which in the aggregate do throw off a mean of as much as 25 inches of the rainfall which may be stored for useful application. This area of 20 millions, representing rather more than half the superficial extent of England and Wales, would consist of the higher grounds of both divisions of the country, and would in the aggregate deliver its surplus waters at an available mean height of at least 150 feet. To reduce this to horse-power by the ordinary calculation would be an easy matter, but I am afraid that the result would not be considered tangible. I am therefore content at this moment to assert that a power equal to at least *half* that obtained from the use of coal might be secured from this source alone. At present it is estimated that 30 millions of tons of coals are used annually for steam power in locomotion and manufactures, and that the power obtained is 1,905,700 horse-power.

To bring the value of the power we possess in the shape of surplus waters better home to the mind in a national point of view, it should be remembered that the chief manufacturing towns are located in the western and northern counties, where the prevailing height of surface is the greatest, and where the quantity of rain and the number of wet days both increase proportionately to height; so that the utilization of the rainfall there becomes a tangible object, and free from those doubts which might appertain to the eastern side of the country. It was owing, no doubt, to the presence and plentitude of water that first led manufacturers to select the western side of England as the best suited for the objects they had in view, and to erect mills in the higher valleys, although the existence of coal on that side of the country has done more than anything else to retain the manufacturing districts where they are. Now that we have had a practical warning of the diminishing supply of coal by an increase in its cost, I think it will be conceded that it is not at all improbable that those branches of trade which are dependent on the use of motive power, may, before long, revert to the use of water in the place of steam. It was only a short time back that three several schemes for the supply of water to the metropolis were presented to the public, of which two were to gain their supply from Wales, and the third from the Lake district. Since that time seasons and circumstances have led several of the towns in the north and west of England to congratulate themselves on the circumstance that these proposals were not successful, and when we see what has been done at Greenock and other places in utilizing the water derived from the drainage of wide areas of land, it will be acknowledged that the country at large will be the gainer by the retention in the manufacturing districts of all the water placed at their disposal.

Greenock, an Illustration of the Profitable Use of Surplus Waters.

No instance could be more apposite to this remark than that afforded at Greenock. There the contributing area of Shaw's Waterworks, which was estimated by Mr. Thom, the engineer, to supply 553,930,000 cubic feet of water per annum, of which the town was to take 18¼ millions, and two lines of mills the remainder, has actually supplied 650,000,000 cubic feet in the year. The Provost of Greenock writes me as follows: "They did not fail us in either 1864, 1868 or 1870; but they did fail to supply all our demands upon them in 1869—the driest year we have had during 40 years. They could have supplied even in that year Mr. Thom's estimate of 554,000,000 cubic feet. The drainage area of the Shaw's works is far from being exhausted; but our storage being limited, we have to waste largely in winter. In 1869 we had sufficient water for domestic purposes, but for some weeks we could not maintain the full supply of 11,000,000 gallons per day for mill power. The Shaw's works cost the original proprietors from first to last about £80,000; and the town is buying them for £170,000. The total supply they give is as above; but, as I have stated, were we to increase our storage, the works would yield a great deal more water."

The Condition of the Thames in Times of Drought.

Before leaving this view of the subject, let me point out that one of the great advantages of storing winter waters, beyond that of turning them to profit for the supply of the population for domestic, trade and sanitary purposes, and as a motive power as coals become dearer, will be their use in maintaining with regularity the summer flow of rivers at a height above the minimum flow of dry seasons. The advan-

tage of extending the principle of compensation—beyond that of merely returning to rivers the same quantity of water that may be taken out of them—to the supply of such a quantity as will enlarge their flow when reduced below a certain quantity, may be illustrated by the condition of the Thames in extreme droughts. The quantity of water flowing just above Kingston, and above the intakes of the water companies, has on several occasions been reduced to 350,000,000 gallons per diem, although engineers generally agree in the opinion that the flow should never be less than 500,000,000 gallons. This deficient quantity is again reduced by that abstracted by the Metropolitan water companies. By the evidence given by Mr. J. Thornhill Harrison before the Water Supply Commission in 1867 (which should be studied by all who are interested in the subject), it appears that on 185 days in the years 1858 and 1859, the river flow was less than 500,000,000 of gallons—that in point of fact there were 34 days when the flow was reduced to 350,000,000—and it would be on such occasions that the stored surplus waters of winter might be used with excellent effect. I need not point out how beneficially the same principle would apply to smaller rivers, whose beds are nearly dried up at certain seasons of the year.

Storage to be adopted for Villages and Rural Districts.

Though the storage of water must commend itself to most people as an object of great importance, the subject would hardly be appropriate if it were limited to generalisms, and were I not to show how it may be usefully applied in rural districts for the village and the farm. I need not recur to that with which we are all familiar—viz., that dry seasons frequently prevail in which the laboring poor of our villages and the stock of our farms have been deprived of their full supply of water, and have had to resort to surface ponds and other means of supply, the quality of which has been as filthy as it could well be. The present summer affords a telling illustration of the miseries of a drought. What would now have been the condition of the surface springs and wells had not the last winter followed an extremely wet one, which had raised the sources of all supply, it is difficult to say, for the misery among the poor and the difficulty of supplying stock are both being felt in an extreme degree in spite of frequent storms. When farming on the hills of Hertfordshire I have myself had to cart the whole of the water used by my horses, cattle, and sheep a distance of 2 miles, while my poorer neighbors have had to pay by the pail for the water they consumed. When the poor are paying by the pail on such occasions, it should be understood that the inhabitants of towns are supplied at all times and in the upper stories of their houses at from 6d. to 2s. per 1,000 gallons, whereas the amount paid by the poor villager, when 1d. is charged for a pailful of 2 gallons, is 42s. per 1,000 gallons. Many are the farms and villages with which we are all acquainted, where the want of water is a most serious item, and it is not many years since that the loss in sheep was very great in some districts. I remember, when on the Romney Marsh, hearing of a large number being lost entirely for the want of water. Now, with mutton at from 10d. to 1s. per lb. this ought not to be, particularly if I am correct in stating that even in the driest winter the excess that exists beyond what is wanted distinctly proves a capability of storage which might easily be brought to bear. The storage of water in small quantities is necessarily an expensive proceeding, for open shallow ponds and reservoirs, encouraging, as they do, the growth and decay of vegetable matters, are to be avoided if possible, and either deep open reservoirs, or covered tanks should be resorted to. The use of concrete as material for the construction of underground tanks, however, reduces the cost very considerably, and will, I hope, help greatly their introduction in rural places. The commonest lime, properly slaked and mixed in due proportions with clean gravel and sand, or with burnt clay ballast, or even sifted chalk itself, if faced with Portland cement, will make admirable tanks. Selenitic cement will probably be found on trial to be equally applicable as a watertight facing, using perhaps twice as much more than Portland cement, which can be done without increase of cost, for it is to be bought at half the price. In using common lime—*i. e.*, the lime of the locality—for the main body of concrete, great pains must be taken to have it thoroughly slaked before mixture, for if this is not done, the lime will afterwards slake in the wall and cause fracture, and fracture means

leakage. It is a great pity that the Government does not institute an inquiry into what has already been done, and authorize actual trials to be made, which would set at rest all doubts as to the capability and cost of making water-tight tanks suitable to different localities and physical conditions. Many valuable details of past experience might be collected if competent persons were engaged to visit different parts of the kingdom and see what has been done, with a view to communicate information to sanitary authorities as to construction and cost. At present they will do nothing for fear of the cost. No money could be better spent, and a few hundred pounds is all that is wanted for the purpose. In some parts of the chalk districts underground tanks have been made by burrowing into the earth and making a chamber or cavern (with an opening at the top for the removal of the soil), which, being lined inside with a thin covering of cement, is made perfectly water tight. Thus the most capacious tanks may be provided for comparatively a few pounds, and districts may be supplied with water which are now destitute of it. This mode of constructing tanks might also be adopted in other geological formations besides the chalk, where the water level is low in the earth with a considerable depth of drained subsoil above it within which to make the "cavern tank." I need hardly say that such a receptacle for water can only be adopted where the soil is naturally drained, and where there is no pressure of external subsoil water. No dwelling or set of buildings, of which the roofs are slate or tile, should be without its tank, unless the occupants are otherwise abundantly supplied. There are few places in England, and certainly none in Wales, in which 20 inches of rain may not be collected with certainty, even in the driest year. Taking an ordinary middle-class house in a village, with stabling and outbuildings, the space of ground covered by the roofs will frequently reach 10 poles; while the space covered by a farm laborer's cottage and outbuilding will be 2½ poles. Assuming that the roof is slate, and the water dripping from it is properly caught by eave-troughing and conducted by down-pipes and impervious drain-pipes into a water-tight tank, sufficiently capacious to prevent overflow under any circumstances, and that by this method 20 inches of water from rain and dew are collected in the course of the year, the private house will have the command of 28,280 gallons, and the cottage 7,070 gallons in a year. To make it clear that this quantity of water can generally be obtained, it should be stated that the proportion lost by evaporation, etc., from a slate covering will not exceed one-sixth of the total quantity of rainfall with the deposition of dew added. A tank 16 feet long and 10 feet wide will hold 1,000 gallons in every foot of depth, and where the water is not wanted for drinking it need not be covered except with a common boarded floating roof of half-inch boards fastened together. This floating roof keeps the water clean, and reduces loss by evaporation. The supply of water to villages, however, should not be dependent upon individual action altogether, for the occupiers themselves are powerless, and cottage owners as a rule are not very liberally disposed in the provision of this necessary of life. There should be some public supply, to render villagers independent of their landlords. Where there exist rivers or streams of pure water near at hand, or where there is a subterranean water-bed easily reached by sinking wells down to it, it is needless to think of storage, but so long as there are large numbers of small communities with rating values so low as to negative the power to charge any large outlay upon them, it behooves us to consider with the utmost care any plan which will enable us to secure a sufficient supply of pure water at a cheap cost. In villages it is unnecessary to aim at the supply of from 20 to 25 gallons a head. Two gallons of water per head per diem is as much as is at present consumed in the majority of villages, and 10 gallons are quite ample. To supply 10 gallons a head should not be a difficult matter; though in cases where there is no land that has been artificially underdrained near at hand allowing of the under drainage water being utilized, or where there is no other means of collecting surface water, it may be absolutely necessary to combine several villages, and by a properly devised system provide for the whole. Much may be done by insisting that cottage owners should provide each cottage with such a tank as I have spoken of, or the share of a tank with other tenants, and by the addition of a common tank to hold a month's supply for the whole village the object might be secured at a fair

cost. I have lately contrived a tank-filter, to be placed *inside* the tank, through which the water passes as it is drawn up by the pump. It is made in earthenware, and sold by Messrs. Doulton & Co. Under propitious circumstances surface waters may be collected in winter for summer use in open reservoirs, but they should never be less than 7½ feet deep in the clear. The water may be delivered in the village street from these reservoirs at from 20s. to 25s. per person, including purchase of land for the reservoir, iron pipes, stand pipes, and taps. Assuming that the money required be borrowed and paid off in thirty years by instalments not exceeding in amount 5 per cent. on the outlay, the result would be a charge of about 1s. or 1s. 3d. per person per annum. I am satisfied, however, that nothing of a tangible character will be done until it can be shown by evidence of actual experience and positive experiments, that reservoirs and tanks can be (comparatively) cheaply made with reference to local features; and that landowners having life interests in property in the neighborhood of villages may collect surface water and construct reservoirs upon their estate to hold it, *by means of borrowed money*, which may be charged upon the property and repaid by instalments. The landowner might then turn water-contractor and supply the neighboring district at an agreed price sufficient to repay him his outlay with some slight profit. But to do this, legal powers are necessary, not only to sanction a tenant for life becoming a water contractor in the way proposed, but to enable sanitary authorities to enter into such an agreement as will make the recipients of the water pay for it within such a pre-determined term of years as will liquidate the cost of the necessary works without pressing hardly upon any one. There can be no irreconcilable reason why such an arrangement should not be made and the cost of the work charged upon the estates on which the water is collected, for the reversionary interest would be benefited by the ultimate possession of a water-property from which a considerable income would be forthcoming after the original outlay is liquidated.

Field Storage.

I have pointed out on more than one occasion how on clay land farms, where thorough drainage has been adopted or is required, the water of under-drainage may be preserved, sometimes in ponds, but more frequently in underground tanks, for the use of the cattle of the farm and for steam cultivation. The facilities with which such provision can be made have not been sufficiently acknowledged. A 10 horse-power engine requires for the cultivation of an acre of land from 100 to 125 gallons of water, and an underground tank capable of holding 2,500 gallons would, therefore, be sufficient for the cultivation of 20 acres. For this quantity the tank should be 8 feet wide, 10 feet long, and 5 feet below the level of the drains, and if concrete were used the cost need not exceed £15 or £16. This tank might be placed in any position convenient for the steam-plough or cultivator, and none will deny the great value of such a supply of water wherever steam is employed in the cultivation of land situated on hills where water is now difficult to get.

Before concluding I must again revert to the more comprehensive view of the subject with which I started. I am fully impressed with the fact that each case of water supply, as well as any other local improvement, must be dealt with upon its own merits; but, to secure any action at all, there must be general obligations in the form of a legal code to be *enforced* by central authority. Permissive laws are more pleasant to British subjects than compulsory ones, but they are absolutely useless in such matters as village water supply. I am quite sure that so long as it is optional with village communities to adopt or reject any proposal for an improved supply in respect of the first essential of life—water—very little will be done. I cannot expect, at a time when the agricultural interest are jealously watching the question of local rating, with a full determination to bring its relations to national taxation to a point, that the opinion I am about to express will be unhesitatingly adopted—viz.: that legislative powers are wanted which shall extend the proper distribution of water to the whole country. From what appears to me to be the mistaken view of the Government, the country has been apportioned into districts for sanitary purposes which are perfectly incompatible with a right treatment of the subjects in view. It may flatter our local prejudices to leave the management of such matters in the hands of boards of guardians as "the rural sanitary authority," and in those of boards of health as "the

urban sanitary authority," but it will not be until some superior presiding authority have jurisdiction over watershed districts, that drainage, sewerage, water supply, and some other kindred objects can be effectually and economically treated. Towns have been sewered without caring what becomes of the sewage; lands have been drained without providing proper outfalls; districts have been improved by trunk drainage without regard to neighboring districts of the same watersheds; and thus one community, or part of a watershed, has been freed of sewage or water, while another has been injured by the discharged liquid. In fact, it would almost seem to be the object of our Legislature, in sanitary matters, first to encourage us to do wrong, then to point out the error we have committed, and, finally, to leave us without any power of rectification. It cannot be expected, while this course of action continues, that any *general* scheme for the storage of water should receive attention, but we may fairly anticipate partial action as the result of recurring droughts like the present one.

REPORT OF EXPERIMENTS UPON VARIOUS AMERICAN BUILDING STONES.

By Q. A. GILLMORE.

The majority of the stones experimented upon were delivered from the quarries in the form of true cubes, measuring 2 in. each way; while some had to be cut to that shape at Fort Tompkins. Generally speaking, the stones were quite true and regular in shape. To distribute the pressure more evenly over the whole surface of the stone, each cube was placed between two cushions of soft pine wood, measuring $2'' \times 2'' \times \frac{3}{8}''$; one of them on the top of the cube, and the other at its bottom.

This arrangement also caused the pressure to act more gradually. The wooden cushions, becoming much indurated by the effects of the pressure, to some extent took the place of mortar, which would be used in actual building.

For iron and wood, Hodgkinson has shown that trial specimens should be at least $1\frac{1}{2}$ times as high as the width of bed; but as stone, except when used in columns, is always made of less height than bed, the cubical form of specimens adopted for the experiments affords sufficient security against angular breakage.

The apparatus used for testing was a hydrostatic press, known as the Hoe press.

The stone to be tested was placed between two pieces of pine wood, as already mentioned, and gradually raised until it touches the lower face of the beam, or cross-head. By continued pumping, the pressure is increased until the stone crushes, and the amount of pressure noted by means of the gauges.

The Report was accompanied by descriptions and diagrams of the press not included above.

The press is supplied with two gauges, one indicating the pressure up to 100,000 lbs., the other to only 5,000 lbs. Both are connected by pipes with the lower end of the cylinder of the ram. Both gauges may be used simultaneously until the capacity of the 55,000 lb. gauge is exhausted, when its connection with the cylinder is shut off by a little valve worked by a hand-wheel. Generally, in testing stones, the lighter gauge is not used.

To check the working of the 100,000 lb. gauge next to the press, another gauge of a similar capacity was employed as a test-gauge. It is attached to the connecting-pipe, near to the pump. These gauges were manufactured in the city of New York, on a modified arrangement of Bourdon's principle.

The 100,000 lb. gauge, like the two others, has a dial-face, traversed by two hands of unequal length. One of these is moved directly by the power of the press; the other (shorter) hand is simply carried along by means of a little projecting pin on the back of the longer hand, or power-needle. The latter returns to the zero-point as soon as the pressure ceases, leaving the shorter hand at the maximum reached on the scale. The record can thus easily be read off, after which the record-needle is pushed back to zero-point in readiness for another trial.

The graduations on the dial-plate of the gauge are fixed by comparison with an air manometer, or with another Bourdon gauge, known to be correctly graduated; and the correctness of the gauge is guaranteed by the manufacturer. But it is, of course, de-

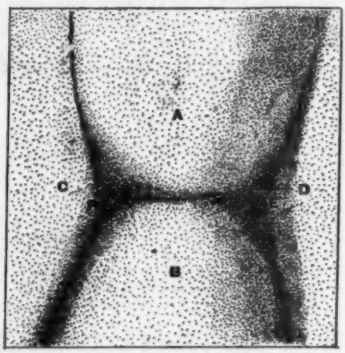
sirable to be otherwise well assured of the accuracy of the records obtained. For the series of experiments herein spoken of, a check was obtained, as already mentioned, by means of another 100,000-lbs. gauge near the pump, so that a test between these two gauges once established, either one can be taken off when rough work is to be done (the most sensitive one always), and the other used, and then both tested again. By this means there can be no change that would escape the notice of an attentive operator, and the actual power used can at any time be tested in full by the application of either gauge to a hydraulic press having a lever accompaniment.

The weight of the movable part of the press is nearly 780 lbs., which, with its own friction, amounts to 800 lbs., nearly. This is to be subtracted from the "strength of specimen," or 200 lbs. from the strength per square inch. Much dispute has existed about the friction of the hydrostatic press when performing heavy duty. Rankine made some rough experiments, which caused him to estimate the friction at 10 per cent. I. Hicks, civil engineer, of Bolton, England, found, by very careful and long-continued trials, made regardless of expense, that the friction varies with the diameter of the ram, and that it is very small and very certain. By his trials the friction of the ram used in the experiments herein discussed (the cylinder being 4¼ in. diameter), would amount to $\frac{9}{10}$ per cent. only, or say 1 per cent. This could and should be tested upon the individual ram; but, without special and costly appliances, it will have to be got at indirectly, and, therefore, slowly.

The Breakage of Stone.

Considering the infinitely varied composition and character of all kinds of rock, it may be said that no material is less calculated to permit the establishment of special laws by a general form of breakage. It may be safely assumed, however, that more numerous and extended experiments, carefully and patiently conducted, will ultimately lead to the development of certain general laws relating to the behavior of stones under pressure, a knowledge of which will be most useful to the engineer and builder.

Homogeneous stones seem, in most cases, to break in the following manner (see diagram): The forms of fragments *a* and *b* are approximately either conical or pyramidal, according as the stone is friable and of obviously granular structure, like sandstone and a few kinds of marble and granite, or compact, such as the true limestones and most marbles and granites. The more or less disk-shaped pieces, *c* and *d*, are detached from the sides of the cube with a sort of explosion, flying off in a more or less intact condition. In *e* and *f*, the stone



is generally found crushed and ground to powder by the attrition of the larger fragments. Of course this general result, or law, is modified by the nature and quality of the "grain" in the stone, and those other causes of irregularity which leave no two cubes of the same strength and condition, although they may have been cut directly apart from each other.

This form of breakage occurs also in non-homogeneous stones broken "on bed;" but it must be remembered that here the modification must be taken into account which "grain" produces as against homogeneity, rendering the object liable to split in rectangular fragments. This frequently lengthens the cone or pyramid in stones "on bed," and causes those set "on edge" to actually split in rectangular disks; the style of splitting being, of course, irregularly modified for different specimens. Sand-cracks, etc., in stones, have also their influence in directing the pressure, and even the difficulty of determining the "bed" in some stones, after being cut, may be a source of errors.

The two strangest cases of abnormal breakage occurred in the United States Quarry limestone (Nos. 29 and 30 of table), the first of which, "on bed," threw off a couple of thin fragments, and then exploded; the balance of the stone being scattered about in minute particles. The second,

Crushing-strength of granites in two-inch cubes.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen.	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds	Pounds.	Pounds.		Pounds.		
1	Blue	Staten Island, N. Y.	On bed	24,000	89 000	22,250	2.861	178 8	Absorption too slow to be taken while weighing.	Cracked before bursting.
2		Fox Island, Me.			59 500	14,875	2.631	164 1		Burst suddenly.
3		Dix Island, Me.			60,000	15,000	2.635	166.5		Do.
4	Dark	Quincy, Mass.		19,500	71,000	17,750	2.660	166.2		Cracked before bursting.
5	Light	do.		18,000	59,000	14,750	2.695	168.7		Do.
6		Tarrytown, Westchester County, N. Y.	On bed	22,000	73,000	18,250	2.655	162.2		Do.
7	Flagging	North River, N. Y.			53,700	13,425	2.690	168 1		Broke suddenly without cracking.
8	Old Quarry	Westerly, Washington County, R. I.			71,000	17,750	2.646	165.6		Do.
9	do	do			69,000	17 250	2.646	165 6		Do.
10		Millstone Point, Conn.			64,750	16.187	2 706	168.7		Do.
11		do			75,000	18,750	2 706	168 7		Do.
12		Sprucehead, Me.			54,000	13 500	2 750	171.9		Do.
13		do			70.000	17.500	2 750	171 9		Do.
14		Hewitt's Island, Me.			57.500	14,375	2 634	164 6		Do.
15		do			60,250	15,062	2.634	164 6		Do.
16	Up river	Richmond, Va.			85,000	21.250				Do.
17	do	do			80,000	20.000				Do.
18		Greenwich, Conn.			45,200	11,300	2.835	177.2		Do.
19		do			46,800	11,700	2.835	177.2		Do.
20	Niantic river	New London, Conn.			50,000	12.500	2.660	166 25		Do.
21	do	do	On edge		56,700	14,175	2 660	166 25		Do.
22		Fox Island, Me	On bed		60,250	15,062	2 660	166 3		Do.
23		do			46,800	11,700	2 660	166 3		Do.
24		Vinalhaven, Me			52 600	13,150	2.720	170.0		Do.
25		do			67,000	16,750	2.720	170.0		Do.
26	Harlem stone	Morrisania, Westchester County, N. Y.			63,200	15,800	2.720	170.0		Do.
27	Tombstone	Sharkey's Quarry, Me.			88,500	22,125	2.720	170 0		Do.
28	do	do			83.500	20,875	2.720	170.0		Do.
29		Richmond, Va			64.250	16,063	2.727	170 5		Do.
30		Cape Ann, Mass.	On bed		59.750	14,423				Do.
31		do	do		78,000	19,500				Do.
32	Porter's rock	Mystic River, Conn.	do		72,500	18,125	2.630	164.4		Do.
33	do	do	On edge		89,000	22,250	2 630	164.4		Do.
34	Gray	Westerly, R. I.	On bed		58,750	14.687	2.670	166 9		Do.
35	do	do	On edge		59.750	14.937	2 670	166.9		Do.
36	do	Richmond, Va	On bed		56.400	14,100	2.630	164 4	1-348	Do.
37	do	do	do		55.500	13,875	2.630	164.4	1-348	Do.
38	do	New Haven, Conn	On edge	29,000	31,000	7,750	2 600	162.5	1-230	Waxy-looking, having a resinous lustre.
39	do	do	On bed		38,000	9,500	2.600	162 5	1-230	Burst suddenly.
40	do	Stony Creek, Conn.	do		60,000	15,000	2.645	165.4	1-201	Do.

Crushing-strength of granites in two-inch cubes.—Continued.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds.	Pounds.	Pounds		Pounds		
41	Gray	Stony Creek, Conn	On edge		67,000	16,750	2 645	165 4	1-201	Burst suddenly.
42	do	do	On bed		63,000	15,750	2.645	165 4	1-201	Do.
43	do	Fall River, Mass	do		63,750	15,937	2.635	165.	1-216	Do.
44	do	do	On edge	33,000	37,000	9,250	2.635	165.	1-216	First split vertically.
45	Rose	Niantic, Conn	On bed		38,200	9,550	2.600	162 5	1-704	Burst suddenly; pores supposed filled with red pigment.
46	Gray	do	do		37,800	9,450	2 580	161.2	1-254	Burst suddenly.
47	Gneiss	Sachemshead Quarry, Conn	On edge		63,750	15,937	2.620	163.7	1-162	Do.
48	do	do	On bed		56,000	14,000	2 620	163.7	1-162	Do.
49	Gray	Hurricane Island, Me	do	33,000	57,700	14,425	2.670	166.9	.....	
50	do	do	On edge		59,750	14,937	2 670	166.9	.....	Burst suddenly.
51	do	do	On bed		44,000	11,000	2.670	166 9	.....	Split off considerably before bursting.
52	Dark, soft-looking	Madison Avenue, N. Y.	do		45,000	11,250	2 920	182 5	0	Probably contains an unusual quantity of iron.
53	do	do	On edge		50,000	12,500	2.920	182.5	0	
54	Gray	Port Deposit, Md	On bed		79,000	19,750	2.720	170.	0	Coarse: strongly dashed with black.
55	do	do	On edge	33,000	52,400	13,100	2 720	170.	0	Do.
56	do	do	On bed		66,000	16,500	2 720	170.	0	Do.
57	do	do	do		60,000	15,000	2 720	170.	0	Burst suddenly.
58	do	Garrison's, North River, N. Y.	On edge	48,000	49,000	12,250	2.580	161.3	1-167	
59	do	do	On bed	51,000	53,500	13,370	2.580	161.3	1-167	
60	do	Palmer Quarry, Me	do	41,000	46,000	11,500	2 590	161.9	1-150	
61	do	do	On edge	58,000	66,000	16,500	2 590	161 9	1-150	
62	do	Rockport, Mass	On bed		65,200	16,300	2.610	163.2	1-152	
63	do	do	On edge	36,000	79,000	19,750	2.610	163 2	1-152	
64	Dark	Du Luth, Min	On bed		71,000	17,750	2 780	173 7	1-711	Syenitic: or, perhaps, trap-rock.
65	do	do	do		76,000	19,000	2 800	175.	0	
66	do	do	do		67,300	16,825	2.800	175.	0	Scant.
67	Purplish	Huron Island, Mich	do		72,500	18,125	2.630	164.4	1-659	
68	Grayish-rose	do	do		82,600	20.650	2 66	166 2	1-600	
69	do	do	On edge		57,700	14,425	2.62	163.7	1-363	Soaked a week for absorption.
70	Grayish	Chaumont Bay, N. Y.	On bed		91,000	22.750	2 65	165.	1-355	Do.
71	do	do	do		64,200	16.050	2 65	165	1-350	Do.
72	do	do	do		70,000	17.500	2.66	166 2	1-557	
73	Dark	Du Luth, Minn	do		68,000	17,000	(*)	(*)	(*)	
74	do	do	On edge		68,750	17.187	(*)	(*)	(*)	
75	Light	Saint Cloud, Stearns County, Minn	On bed		64,000	16.000	2.69	168 2	1-239	
76	do	do	On edge		74,000	18,500	2 69	168.2	1-239	
77	Bluish-gray	Keene, Cheshire County, N. H.	On bed		41,000	10 375	2.656	166	1-300	Used in inside of new capitol, Albany, N.Y.
78	do	do	do		51,500	12,875	2.656	166.	1-300	

Crushing-strength of limestones in two-inch cubes.

1	Glen's Falls...	Glen's Falls, Warren County, N. Y.....	On bed ..	.....	45,900	11.475	2 700	168.8	.....	All the stones named below, burst without cracking, except those noted to the contrary.
2	..do.....	... do	On edge .	.....	43,000	10,750	2.700	168 8	.....	
3	Lake	Lake Champlain, N. Y.....	On bed ..	.....	100,000	25,000	2.75	171.9	.....	
4	... do	....do.....	On edge .	60,000	86,000	21,500	2 75	171.9	.....	
5	....	Canajoharie, Montgomery County, N Y.	On bed ..	70,000	82,800	20,700	2.685	169.8	.....	
6	.....	....do.....	On edge .	70,000	77 000	19,250	2 685	169.8	.....	
7	North River....	Kingston, N. Y.....	On bed ..	40,000	55,600	13,900	2.69	168 2	.....	
8	....do.....	... do.....	On edge .	.....	44,200	11,050	2 69	168.2	.....	
9	....	Garrison's Station, N. Y.....	On bed ..	.....	74,000	18,500	2 635	164.7	.....	
10	.....	....do.....	On edge .	.....	73,100	18,275	2.635	164 7	.....	
11	.....	....do.....	On bed ..	.....	71,000	17,750	2,62	163.7	.....	
12	....	....do	....do....	.....	71,0 0	17,750	2 616	163.5	.....	
13	.....	....do.....	.. .do....	.....	75,100	18,775	2.616	163.5	.....	
14	White	Marblehead, Ohio	....do....	....	45.000	11,250	2.4	150.	1–30	
15	... do....	....do.....	....do....	.....	42.800	10,700	2.4	150.	1–33	
16	....do	....do.....	....do....	.....	50,400	12,600	2.48	155.	1–33	
17	....do.....	Joliet, Ill.....	....do....	.....	51,100	12,775	2.54	158 8	1–51	
18	....do.....	.. do.....	.... do....	.....	67,600	16,900	2 60	162 5	1–139	
19	....do.....	....do....	....do....	....	58,600	14,650	2.54	158 8	1–91	
20	Drab	Lime Island, Mich.....	....do....	... .	72,000	18,000	2.50	156 3	1–76	
21	....do.	....do.....	....do....	.....	100,000	25,000	2.58	161.2	1–139	
22	....do	....do.....	....do....	.....	61,700	15,425	2.551	159.4	1–56	
23	....do.....	Marquette, Mich.....	On edge .	... ...	32,200	8,050	2.34	146.3	1–23	Rather a clay stone.
24	....do	....do.....	On bed ..	.....	31,300	7,825	2.34	146.3	1–23	
25	....do	....d	On edge .	.....	30,400	7.600	2.34	46.3	1–23	
26	Bluish-Drab...	Big Sturgeon Bay, W's.....	On bed ..	.....	86,000	21,500	2 78	173.8	1–399	A remarkably solid, stable stone.
27	....do....	....do	On edge .	.....	66.750	16,687	2 75	171.9	1–678	
28	....do	Le ont Quarry, Cook County, Ill	On bed ..	.....	48,000	12,000	2.645	165 3	1–89	
29	....do.....	....do	On edge .	.....	56 000	14,000	2.645	165 3	1–89	
30	Dark	Bardstown, Ky.....	On bed ..	.....	65,000	16,250	2.67	166.9	1–80	Used for Louisville and Portland Canal.
31	....do....	....do.....	On edge .	.....	60.000	15,000	2 67	166.9	1–80	Do.
32	White	Joliet, Ill.....	On bed ..	.....	45,000	11,250	2.55	159.3	1–35	Specimens scant in measure, and not so good as Nos. 17 and 18 of same.
33	....do	.. do.....	On edge .	.....	28,200	7,050	2,55	159.3	1–35	Do.
34	Dark-Drab.....	Billingsville, Cooper County, Mo	On bed ..	.....	26,600	6,650	2.32	145.	1–23	
35	....do	....do.....	On edge .	.....	29,000	7.250	2.32	145.	1–23	
36	Blue	Williamsville, Erie County, N. Y.....	On bed	.....	49,000	12,250	2.64	165.	0	
37	....do	....do.....	On edge .	.....	49,500	12 375	2.64	165.	0	

* See Nos. 64, 65, and 66.

Crushing-strength of marbles in two-inch cubes.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds.	Pounds.	Pounds		Pounds.		
1	East Chester	Tuckahoe, Westchester County, N. Y.	On bed	.....	51,800	12,950	2 875	179.7	*	
2	....do	....do	....do	.....	48,200	12,050	2.875	179 7	*	
3	Common Italian.	Italy	....do	.....	45,000	11,250	2.690	168 2	*	
4	....do	....do	....do	.....	52,250	12,062	2.690	168.2	*	
5	Vermont	Dorset, Bennington County, Vt	....do	.....	30,450	7,612	2.635	164.7	1-17	Crushed with slight explosion.
6	....do	....do	On edge	.....	34,680	8,670	2.683	167.8	0	Do.
7	Drab	Mill Creek Quarry, Quincy, Ill	On bed	.....	38.750	9,687	2 570	160 6	1-180	Crushed with louder explosion.
8	....do	....do	On edge	.....	39,150	9.787	2.510	156.9	1-74	Do.
9	....do	North Bay Quarry, Door County, Wis.	On bed	.....	80,100	20,025	2,800	175.	0	Crushed with quiet explosion.
10	....do	....do	On edge	.....	54,800	13,700	2 800	175.	0	Crushed with slight explosion; sand-cracks.

* The absorption of most appears so small, and occurs so slowly, that they were left for soakage hereafter.

Crushing strength of sandstones in two-inch cubes.

1	Brown	Little Falls, N. Y	On bed	.....	39.400	9.850	2.250	140 6	1-34	Used in building Trinity Church, New York City. Had been exposed for years to weather and become harder. Broke suddenly, without previous premonition.
2	....do	....do	On edge	.....	36,600	9,150	2.250	140.6	1-34	
3	Gray	Bellville, N. J	On bed	.....	46,800	11,700	2.259	141.	1-27	Broke suddenly.
4	....do	....do	On edge	.....	41,000	10,250	2.259	141.	1-27	
5	Brown	Middletown, Conn	On bed	.....	27,800	6,950	2.360	148 5	1-40	Trinity Church, Brooklyn, N. Y., built of it.
6	....do	....do	On edge	.....	22,200	5.550	2 360	148.5	1-40	
7	Red	Haverstraw, N. Y	On bed	.....	17,400	4,350	2,130	133 1	1-23	
8	do	....do	On edge	.....	16,100	4,025	2,130	133 1	1-23	
9	Pink	Medina, N. Y	On bed	.....	69,000	17,250	2.410	150 6	1-55	Lilac in color.
10	....do	....do	On edge	.....	59.250	14,812	2.390	149.3	1-51	More purple than last.
11	Drab	....do	On bed	.....	70,900	17,725	3.420	151.1	1-70	
12	....do	Berea, Ohio	....do	.....	41.000	10 250	2,110	131.9	1-16	Very friable, like sugar.
13	....do	....do	....do	.....	33.200	8,300	2 130	133 1	1-20	
14	....do	....do	....do	.....	29 000	7.250	2 200	137.5	1-24	
15	....do	....do	....do	.....	31,000	7,750	2,110	131.9	1-19	
16	....do	....do	....do	.....	38,400	9,600	2,140	133 7	1-22	
17	Brownish-gray	North Amherst, Ohio	On edge	.....	21,800	5,450	2 140	133 7	1-19	
18	....do	....do	On bed	.....	26,600	6,650	2.190	136.9	1-19	
19	....do	....do	....do	.....	23,100	5,775	2 160	135.	1-19	
20	Drab	Vermillion, Ohio	....do	.....	33,800	8,450	2.160	135.	1-19	

20	Drab	Vermillion, Ohio	do			35,000	8,750	2 165	135.3	1-19	
21	do	do	do			33 000	8,250	2 165	135.3	1-19	
22	do	do	do			24.000	6,000	2 165	135.3	1-19	
23	do	do	do			35,400	8 850	2 1 7	134 8	1-19	
24	do	do	do			31,400	7,850	2 157	134 8	1-19	
25	do	do	On edge			27,500	6,875	2.157	134.8	1-19	
26	Purple	Fond du lac, Wis	On bed			25,000	6 250	2.220	138.8	1-22	
27	do	do	do			24,900	6,225	2 220	138.8	1-22	
28	do	do	On edge			20,440	5,110	2 220	1 8.8	1-22	
29	do	Bass Island, Wis	On bed			21.800	5,450	2 040	127.5	1-15	
30	do	do	do			17,000	4,250	2 040	127.5	1-15	
31	do	do	On edge			17.150	4,287	2.040	127.5	1-15	
32	do	Marquette, Mich	On bed			20,200	5,050	2 285	142.8	1-32	
33	do	do	do			29,100	7,275	2.285	142.8	1-32	
34	do	do	On edge			22,6 0	5,650	2 285	142.8	1-32	
35	do	do	On bed			29 800	7,450	2.160	135.	1-20	
36	do	do	do			29,800	7,450	2 160	135.	1-20	
37	do	do	On edge			22,920	5,730	2 160	135.	1-20	
38	do	do	On bed			21 000	5,250	2.170	135.6	1-20	
39	do	do	do			25,080	6,270	2.170	135.6	1-20	
40	do	do	On edge			19,000	4,750	2.170	135.6	1-20	
41	Red-brown	Seneca freestone, Ohio	On bed			38,750	9,687	2.390	149 3	1-32	
42	do	do	On edge			42,000	10.500	2 390	149.3	1-32	
43	Olive-green	Cleveland, Ohio	On bed			27.200	6 800	2 240	140.	1-37	
44	do	do	On edge			31,640	7,910	2 240	140.	1-37	
45	Whitish	Marblehead, Ohio	On bed			31,750	7,937	2,310	144 4	1-19	Rather a chalky limestone.
46	do	do	On edge			27,400	6,850	2 310	144 4	1-19	Do.
47	Brown	Albion, Orleans County, N. Y.	On bed			54.000	13,500	2,420	151 2	1-44	
48	do	do	On edge			45,400	11,350	2,420	151.2	1-44	
49	Pink	Kasota, Le Sueur County, Minn	On bed		27,000	42,800	10,700	2 630	164.4	1-56	Calcareous sandstone.
50	do	do	On edge			46.700	11,675	2 630	164.4	1-56	
51	Light-buff	Fontenac, Goodhue County, Minn	On bed			25,000	6,250	2.325	145.3	1-28	
52	do	do	On edge			31,100	7,775	2 325	145 3	1-28	
53	Craigleith	Edinburgh, Scotland	On bed			48,000	12,000	2.260	141.3	1-34	
54	do	do	On edge			45,000	11,250	2.260	411.3	1-34	
55	Freestone	Dorchester, New Brunswick	On bed			36.600	9,150				
56	do	do	do			37.650	9,412				
57	Olive	do	do			17,000	4,250				
58	do	do	On edge			24,2.0	6,050				

"on edge," broke into wedge-shaped disks of moderate size.

The Du Luth, dark granite (Nos. 73 and 74) split "on bed" into two disks nearly equal in size, which were forced a ½ in. apart, though pressed at right angles to their line of motion by a force of 68,000 lbs. The second specimen "on edge," acted in precisely the same manner. A very curious result of this experiment was the fact that the pine cushion blocks, which usually stand a pressure of 80,000 or 90,000 lbs., and become indented but comparatively not torn or injured, were in this case spread over the pieces *a* and *b* as though the wood had been crushed to fibre in liquid resin and painted over with a brush, part of it coming down in rough festoon between the separated parts of the stone.

But notwithstanding the diversity of phenomena attending the breakage of stones by direct compression, the obvious difference between the fragments produced by that operation and those fragments obtained by the stonecutter's hammer is suggestive of laws, modified but always existing, and capable of being, at least, roughly classified.

Specific Gravity.

The stones whose resistance to crushing pressure had been tested were also experimented upon in relation to their specific gravity. In the course of these investigations, it was sometimes necessary to be content with rather small fragments of stone, of not more than 15 to 18 pennyweight; but generally they weighed from 1 to 2 ounces.

On commencing this part of the work, some doubt was felt in regard to the best means of obtaining the correct displacement of porous stones; and all stones are more or less porous. It appeared evident that in weighing the stone first in air and then in water, an error would be committed by saturation. The first idea, to give the stone a coating of thin varnish, was abandoned, because, although the pellicle would be thin, yet no means could be taken to know precisely what its thickness was, or what it amounted to in its effects. The second idea, to soak the stone in very fluid resin, the pellicle to be washed from the surface before dry, was given up because it was desirable to preserve the specimens intact for experiments on freezing and other tests.

The plan finally adopted was, first, to remove from the stone all loose particles, and round off all sharp corners and edges, bringing it, in fact, practically to that condition commonly known as "water worn." It was then carefully weighed in air, immersed in water, and allowed to remain there un il all bubbling had ceased, and its weight taken. It was then taken out of the water and weighed again, in its saturated condition, with the precaution of previously denuding the stone of superabundant water by being compressed lightly in bibulous paper. The specific gravity is now found by dividing the weight of the stone when perfectly dry, by its weight in the air, after having been saturated, *minus* its weight in water.

This may also be expressed by the formula—

$$\text{Specific gravity} = \frac{W}{W_{''} - W_{'}}$$

W representing weight of dry stone in air; $W_{''}$ representing weight of saturated stone in air; $W_{'}$ representing weight of stone immersed in water.

In determining the specific gravity of stone, the weight of water was assumed to be 62½ lbs. per cubic foot.

Ratio of Absorption.

The term, "ratio of absorption," simply expresses the weight of water absorbed by the stone as compared with the weight of the dry stone; *i. e.*, if the stone, when dry, weighs 300 units, and the column of "ratio of absorption" shows the fraction $\frac{1}{300}$, it means that, by immersion in water, the stone will absorb 1 unit of it, weighing 301 units immediately after its removal from the water

The method adopted for ascertaining the specific weight of stone furnished at the same time the means to determine the "ratio of absorption." The weight of the saturated stone *minus* the weight of the dry stone gives, as a result, the amount of water absorbed. This might, perhaps, more correctly be called the "avidity of absorption," since it was limited to the period of bubbling. Some few stones, having been kept in water for several consecutive days, showed a slight increase in weight.

Since the capacity of a stone to absorb water has much influence on its durability, even during the warm season, and far more so in cold weather, the addition to the tables of this column was deemed advisable. (For tables see pp. 555, 556, 557, 558, 559.)

THE NATURE OF PROPERTY IN PATENTS AND THE LEGAL EFFECT OF THE ORDINARY FORMS OF ASSIGNMENT.

By EDWARD E. QUIMBY

Written for Van Nostrand's Magazine.

The ordinary form of assignment of an undivided interest in letters patent is as follows, to wit.:

"In consideration of one thousand dollars to me paid by A. B., of ——— I do hereby sell and assign to the said A. B., one undivided fourth part of all my right, title, and interest in and to the letters patent of the United States, No. — for an improvement in ——— ———, granted to me ——— the same to be held and enjoyed by the said A. B. to the full end of the term for which said letters patent are granted, and for the term of any extension thereof, as fully and entirely as the same would have been held and enjoyed by me if this assignment and sale had not been made.

"Witness my hand this —— day of etc.
"C. D."

It is settled that the privilege conferred by a patent is an incorporeal chattel impressed with the character of personal estate by being made assignable, and also that joint patentees or joint owners of a patent, in the absence of special agreement, are tenants in common and not co partners.

Hindmarch on Patents, Curtis on Patents, Clum vs. Brewer, 2 Curtis, 524, Parkhurst vs. Kinsman, 1 Blatchford, 496, Mather vs. Green, English Law Journal, vol. 35, p. 1, Vose vs. Singer, 4 Allen, Mass. R., 226.

An attempt to apply to tenancy in common in patents the rules of law defining the rights, powers, and duties of tenants in common in other kinds of property meets with great if not insuperable difficulties, arising from the peculiar nature of the property in question. A patent right is peculiar in having a defined period of existence, during which it is indestructible—unlike cattle, it is not liable to the uncertainties of animal life, and unlike vessels, it is not liable to shipwreck, neither can it be taken physical hold of and removed from the possession of its owner. Originally, as a rule, it has no ascertained money value. The theory of its existence is that it is *sui generis*; there is, therefore, no rule of comparison nor principle of measurement for determining its money value. It may be made valuable by the employment of capital and labor in a skilful use of the privilege which it confers, or on the other hand it may turn out to be worthless and involve a total loss of the capital and labor expended upon it, irrespective of the degree of skill exercised. A ship may be wilfully burned or a colt wilfully killed by one tenant in common, in either case, who thus may totally destroy the common property. In such event the measure of damage to the other owners is easily ascertained, because, under similar circumstances, one ship has substantially the same value as another ship of like tonnage, materials and construction, and one colt the same value as another of like age, condition and strain of blood. But a patent right is a right to exclude all the world other than the grantees from the use of the privilege conferred by the patent, and there is no exclusion of any one of the grantees. One tenant in common cannot take away from his co-tenants their privilege without their consent. And exercise of the patent privilege by one tenant, instead of being a destruction of the common property, is usually a benefit to the other tenants by creating a demand for the thing patented, which they can take advantage of and participate in filling.

One of the elements of value in a patent right is its period of continuance. As the patent has a limited duration, the element of value suffers a conspicuous decrement from day to day. If the patent is commercially valuable, this value is at least discovered and established, if not created, by the act of exercising the patent privilege.

The ship may never have left the stocks, nor the colt its mother's milk, yet both ship and colt have an initial value, ascertainable by comparison, which may be regarded as so much capital representing the cost of building the ship or of breeding the colt. A patent right, on the contrary, derives its money value from a skilful exploiture which results in profit. An unskilful exercise of the privilege may result in loss irrespective of the utility of the invention, and it is no-

where pretended mere co-ownership creates any liability on the part of one tenant in common to contribute any portion of such loss made by another tenant in common. Yet the prevailing notion is that each owner of an undivided interest———— in a patent is necessarily entitled to a corresponding share of all profits derived from the use of the patent. This would only be true if it were so expressly set forth and provided for in the assignment, or by agreement between the co-owners. It is obvious that in this and in various other ways the title to the patent may be kept in its entirety, the element of exclusiveness be presented and the patent administered for the joint account of the several owners pro rata.

The only thing in the foregoing form of assignment tending to support the theory that an accountability is created among the owners, is the use of a fraction to designate the measure of their several interests. It will not do to predicate upon this alone a contract, agreement, or condition *pro tanto*, that all the owners shall share *pro rata* in profits which may be realized by either one from the successful employment of his own exclusive capital and skill when they are concededly not liable to contribute if loss results from the unsuccessful employment of capital in the exercise of the patent privilege.

Public interest has dictated the establishment of special rules of law governing tenancy in common in certain cases, and it has been well said with reference to shipowners, that "a personal chattel vested in several distinct proprietors, cannot possibly be enjoyed advantageously by all without a common consent and agreement among them and that the best method of forcing them to a common consent for their common benefit, is to leave it to themselves either to enjoy their common property by agreement, or to suffer it to remain unenjoyed or perish by their dissension."

The public interest in a patent right is not that the invention shall be locked up for the term of the patent, but that the patent privilege shall be exercised. The consideration for the grant is that something new and useful to the community has been disclosed by the grantee.

There appears to be an implied contract that the patent shall be exploited, and the public interest is clearly on the side of the part owner who either works the patent himself or licenses others to work it, and thus introduces the improvement into public use.

A patent has originally the character of a monopoly, and joint owners of it may, by agreement among themselves, preserve that character for it as against all the rest of the world; but it would be contrary to public policy to enforce such agreement when none such exists, it being to the interest of the public that there shall be competition among the owners tending to enlarge the production and reduce the cost of the thing patented.

In the absence of specific provision for perpetuating the monopoly, or, in other words, preserving the title to the patent in its entirety, it seems that assignees under the foregoing form are admitted by the grantee to the concurrent exercise of his patent privilege without liability to further payment or accountability therefor.

A privilege is a thing that a person has or has not; it is unsusceptible of division, and the privilege conferred by a patent is a mere naked right which would be inseparable from the person of the grantee but for the fact that every patent is by law assignable either as to the whole interest or any undivided part thereof. The fractional expression in the assignment determines the share of the respective owners in case of a sale of the entire interest by their consent, but no one owner can be compelled to consent to a sale nor be prevented from demanding any price he chooses for his interterest, nor can his interest be sold and delivered without his consent. That is to say, each fractional interest is the subject of a distinct independent ownership. The property so shared was originally a right of the patentee to exclude all the rest of the world from the exercise of the patent privilege, *pro tanto* a right to remove the exclusion as to individuals, or, in other words, to license others to use the thing patented. By the act of assigning a part interest, the patentee gives up the right to exclude the individual who becomes his assignee, and, of course, the power of granting exclusive license rights thereafter; because, any territorial license right granted by the patentee thenceforth is taken subject to the condition that the assignee may step in and concurrently exercise the privilege of the patent in the same territory. Neither the patentee nor his assignee as co-owners of the whole interest, can be compelled to concur in grant-

ing an exclusive territorial license right, nor be prevented from demanding and retaining what consideration they may choose as the price of their assent thereto. Nor is there anything to prevent the coincident exercise of the patent privilege either by the parties themselves or by their legal representatives. By a common agreement among themselves, they may preserve the exclusive character of the right, and continue its exercise as a monopoly, or, by their dissension, they may permit that element of the value of the patent to perish.

Bearing in mind that the patent privilege includes the right of licensing, the legal proposition may be thus stated:

Patent property consists of an assignable privilege, having originally an exclusive character which may or may not be preserved at the pleasure of the grantee. If the grantee assigns an undivided part interest in his patent without the precaution of exacting an agreement regulating the use of the privilege assigned, he, by that act, divests himself of the sole power of exclusion which he theretofore possessed, and the common property thenceforth is simply a common privilege, the free exercise of which by either part owner cannot be held to be an invasion or infringement of the rights of the other part owner.

This state of things may be remedied and the rights of the parties preserved by a special agreement between them, or by a territorial division of the patent, or by assignment of the whole interest to a trustee empowered and directed to administer the patent for the account of the several owners, pro rata.

RAILWAY GIRDERS FOR THE METRE GAUGE.

From "The Engineer."

The designing of iron girders of long span, which are intended to carry comparatively a very light rolling load, is, in an economical point of view, an unsatisfactory task for an engineer. It is, in fact, well nigh impossible to combine the requisite elements of strength and stiffness without sacrificing some material in one or other, or probably in both. In a skilful and judicious design, especially adapted for the particular duty it has to perform, and not modelled after an old stereotyped pattern, a considerable amount of the material constituting essentially the strength of the structure, may be made useful in insuring to some extent the other equally necessary element. But unfortunately, on the other hand, material employed solely as bracing, or with a view to obtain stiffness, cannot be rendered serviceable to resist strains, which must be provided for by so much actual metal in the flanges and web of the girder. A prevailing fault in many of the girders designed for this relative proportion of the different loads to which they are subjected, is that while the element of strength is insured to a superabundance, that of stiffness is considered to be necessarily extraneous. In a word, the girders are built first and stiffened afterwards. A precisely analogous instance frequently presents itself in edifices in which true esthetical principles are departed from. The building is constucted first and ornamented afterwards. No doubt, in the first case, some rigidity must be provided subsequently to the erection of the girders; and, in the second, some ornamental details and embellishment must be added after the building, in a structural sense, is completed. But the addition of a minimum amount of stiffness to a girder by extraneous bracing, and the similar addition of surface decoration to a large edifice, are very different things from totally ignoring these details in the design of these two classes of structure. The economical merit of any particular type of girder will depend, not, as is generally considered, upon the actual amount of material in its flanges and webs, but upon the total amount required for a pair of them when they are braced together so as to constitute a bridge.

In investigating the type of girders best suited to fulfil the double conditions of a long span and a light rolling load, we shall omit the solid-sided, or plate form, for two reasons. In the first place, there is no economy in the employment of this description of girder, even in very small examples, when compared with the open web or trussed form; secondly, the impossibility of uniting the flanges and web with any mode of connection except rivets, renders it

inapplicable to those cases where from various causes, pins must be used for that purpose. We always have advocated the used of rivets when possible instead of pins, and see no reason to change our opinion. At the same time, we freely admit that cases may arise where the latter means of connection are the only ones available. The ordinary form of open web girder adopted for India, in which country the metre-gauge will have a great scope, is either the Warren or the lattice, in which the upper and lower flanges are horizontal. In every girder in which this horizontality of the two flanges obtains, there is a loss of metal towards the ends, and it is impossible to avoid it. As the span increases this loss also increases, and is still further augmented by the special considerations under notice.

For the sake of example, let us select a girder of a span of one hundred and fifty feet. The breadth of the top flange, if built of the ordinary trough shape, cannot be less than thirty inches, and the minimum thickness of a single plate half an inch. In addition, there are the side plates and angle iron by which the web is attached, which must be continuous throughout the whole length of the girder. Allowing for all possible reduction of sectional area in the side plates, there will still be, at least, thirty inches of gross sectional area at the ends, a quantity greatly in excess of the theoretical requirements. Now for the web. The rolling load for one girder of this span, according to the data prescribed for Indian bridges by the Government, is fifty-eight tons, or only a trifle over one-third of a ton per foot run. In a girder of this size the bars in the web would be double, and supposing them inclined at 45 deg., the strain upon each central bar would be just five tons, requiring theoretically only one inch of sectional area. It is needless to observe that a bar nearly fourteen feet long, under these circumstances, must have a sectional area four or five times this amount to fulfil practical exigencies. In a bridge a mile long, of which there are several examples in India, and in which the girders are of the horizontal type, the loss of metal from these two circumstances combined must be enormous. There are, notwithstanding, many practical advantages possessed by the horizontal girder which must not be underrated. It is neat in appearance and simple in construction. All the bars, with the exception of a few terminating over the end pillars, are of the same length, and inclined at the same angle, so that but few templets are required. It also possesses the merit of being able to be loaded on either flange, or on both at the same time, so that in the latter event two roadways can be taken over it, of which there are several examples in India and other foreign countries.

The objection against the loss of metal at the ends of the flanges on the horizontal girder is very successfully met, when the bridge consists of some half dozen spans, by making the girders continuous. The loss then is confined to the two obtuse ends, and is trifling in a bridge of many spans. The ends of the otherwise individual girders are now rendered continuous over the piers, and all the metal in the flanges is utilized. Moreover, the principle of continuity is extremely well adapted in an economical point of view to the conditions of the problem before us, which include a relatively large span, that is, a heavy permanent or dead load, with a light live or rolling load. Under these circumstances the position of the points of contrary flexure, or points of inflection, alter very little under the action of the passing load, and the full benefit of the continuous system is obtained. But in order to benefit by this happy proportion between the permanent and the rolling load, one other point must be satisfactorily settled. It is an essential feature of the continuous principle that the foundations should be of the most stable and unyielding character. A slight settlement in a pier or abutment, which would produce no injurious effect upon independent girders, would completely destroy the efficacy of continuous ones, and altogether obviate the peculiar advantages to be derived, in such an instance as the present, from the adoption of the principle. The foundations in India are notoriously insecure, and it would be obviously a most injudicious plan to employ as a rule continous girders in such a country. The adoption of the continuous system will not make any difference with regard to the loss of metal in the web already referred to.

Returning to the theoretical part of the subject, the object to be aimed at in designing girders for the purpose in point, is evidently to select such a form as will enable the strains upon the flanges to be more equalized and more uniformly distributed, and those upon the central part of the web

bars to be either increased or confined to one character, compressive or tensile, but not both. The type of girder which fulfils the former of those conditions with respect to the flanges is the bow and string, and with proper adjustment it may be caused to fulfil those also required with respect to the central bars of the web. In the bow and string girder the strains on the bow and string are practically uniform throughout, so that there need be no loss of material in the flanges.

It will be seen on a little investigation that this form of girder presents advantages for very much reducing, and in some instances, for entirely obviating the loss of material which occurs in the web of parallel girders. Under any conditions of loading the strains upon the bars in the web of a bow-string girder are very considerably less than in those of a parallel girder placed under similar conditions of span and loading. With a uniformly distributed static load the strains upon the bars are all tensile, but so soon as a rolling load is brought upon the structure they are subjected to a compressive strain to a greater or lesser extent, according to the successive positions of the load, and the necessity for counterbracing these is at once apparent. If the proportion of the permanent to the rolling load could be adjusted so that the tensile strains upon the bars, due to the action of the former description of load, were always in excess of those produced by the latter, there would be no necessity for counterbracing. Thus, not only would the sectional area of the web be reduced to nearly the theoretical amount, but one of the great difficulties in the economical designing of these structures removed, namely, the securing of long struts from deflection. Having admitted that all girders, both separately and when combined so far as to constitute a bridge, require a certain amount of extraneous bracing, it remains to investigate whether a pair of parallel or a pair of bow-string girders require the most bracing. One practical objection against the bow-string is that it can only be loaded on the bottom flange; therefore in comparing the two as a bridge, the assumption of loading on the lower flange must be conceded.

The depth of the parallel girder is constant, so that when the girders are deep enough to be braced together overhead, the bracing must be continued at intervals over their whole length. This is not the case with the bow and string, whose maximum depth at the centre is equal to the constant depth of the parallel girder, so that one bracing overhead would be required only in the immediate vicinity of the centre. Moreover, the liability to vibration of a girder whose depth diminishes regularly from the centre to almost nothing at the ends, is manifestly very much less than that of another form in which the depth is constant, and the ends free to move with a leverage equal to that depth. On the whole it appears that the bow and string is the preferable form for girders for the metre gauge, even if the parallel girders were made continuous. As independent girders they are, no doubt, inferior to the other type.

There are one or two other forms of girders well suited to this particular proportion of dead and live load, which we shall refer to on another occasion. As the metre gauge is now definitely adopted for many Government railways in India, the subject of the most suitable form and principle of truss for the purpose is deserving of all consideration.

ENGINEERING INSTRUMENTS OF ALUMINUM.

By S. V. CLEVENGER.

Written for Van Nostrand's Magazine.

When this beautiful metal was too costly to warrant its being generally used for the innumerable purposes to which it is adapted, there was a good reason for its being neglected by manufacturers of scientific instruments, but since the mode of its production was so much simplified by Bunsen and Deville, causing its value to fall from £3 in A. D. 1856, to 11s. per oz. in the succeeding year, it is unaccountable that aluminum should not be utilized in the construction of some, at least, of the appliances to which, above all metals, it is so well suited.

Take the single item of engineering instruments where weight is an objection and increased size within certain limits desirable.

The ordinary transit weighing eleven pounds, may be made of aluminum to weigh three pounds without decreasing its

size or increasing its cost, or the arcs may be made five times as large under the same weight; the solar compass could have all the advantages arising from diminished liability to errors of reading, and the certainty of readily determining fixed or variable errors of graduation or construction.

Aluminum has many advantages over brass, silver, nickel and steel, and combines all their qualities without their objectionable weight, and a simple statement of its various recommendations to instrument makers will be all that is needed to make it known as theoretically the metal for the purpose.

Its lustre is bluish white.

It is non-magnetic and therefore will not deflect a needle by its presence.

It can be electro-deposited.

Its price is one-half that of good silver.

It neither rusts nor tarnishes so readily as brass, unless when in very thin sheets.

It is not acted upon by air or water at common temperatures, damp air slowly tarnishing it. When intensely heated in a current of air it suffers only slight oxidation; heated to redness in an atmosphere of steam it slowly oxidizes.

It is readily acted upon by hydrochloric acid which evolves hydrogen and forms chloride of aluminum. Sulphuric and nitric acids do not affect it at common temperatures, but when boiled in the latter it oxidizes as long as heat is maintained. Boiling in acetic acid does not affect it. Concentrated alkaline solutions slowly oxidize it and hydrogen is liberated. It is not affected by sulphur or sulphuretted hydrogen, or by solution of the alkaline sulphides.

The alloys with other metals are too brittle to be made use of for the purposes of this article.

Atomic weight 27.5; specific gravity, 2.67 when rolled, when cast, 2.56.

It is more malleable than tin, platinum, lead, zinc or iron, being next to copper, and less malleable than gold or silver.

Next to copper it is more ductile than zinc, tin and lead, and less ductile than gold, silver, iron and platinum.

Compared with other metals under the same bulk, aluminum weighing 1.

Platinum,	7.9	Gold, .	7.7
Mercury, .	5.4	Lead, .	4.5
Silver, . .	4.1	Copper, .	3.6
Nickel, . .	3.6	Iron, .	3.1
Tin, . . .	2.9	Zinc, .	2.8

Its electrical conduction is greater than that of iron or zinc, being 33.76 where silver is 100.

Its fusibility is at a point little less than that of silver, 1750 deg. Fahr.

Dr. Clemens Winkler, in the "Deutsche Industrie Zeitung," says it can be worked into any shape, and that there are no deleterious effects arising from working in it.

It is largely manufactured in England and France, there being a large factory at Newcastle, where it is extracted from the French mineral *Vauxite*.

New methods are being discovered for obtaining it from kaolin or clay, inexpensively, and considering that it combines the ductility and malleability of copper, with vastly more than the strength of steel (it is placed by some as 13 times stronger) with the lightness of chalk, it certainly should take the place of metals less adapted to purposes where strength, lightness and bulk are desiderata, as is indisputably the case in the manufacture of fine instruments for engineering field use.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—October 21, 1874.—A stated meeting was held at 8 o'clock P. M. Prof. Robert H. Thurston read a paper on the "Efficiency of Furnaces burning wet Fuel," which was followed by discussion.

Attention was called to two pieces of one of the main cables of Fairmount Suspension Bridge (Philadelphia), erected by Ellet, about 1840—one from near the centre of the span, and the other from over the top of the tower—which, with a communication from the donor, Mr. Joseph M. Wilson, of Philadelphia, referring to them, were presented to the Society.

November 4, 1874.—The twenty-second annual meeting was called to order at 11 o clock A. M., Mr. Julius W. Adams, President, in the chair.

The Annual Report of the Board of Direction on the affairs, and of the Treasurer on the finances of the Society, were read and accepted.

The Society proceeded to elect officers for the ensuing year; ballots were taken and the following declared elected: Messrs. Julius W. Adams, President; W. Milnor Roberts and Theodore G. Ellis, Vice Presidents, Gabriel Leverich, Secretary; James O. Morse, Treasurer; Octave Chanute, John Bogert, Charles Macdonald, Francis Collingwood, and George S. Greene, Directors.

A recess for one half hour was taken.

The meeting was called to order at 2 o'clock P. M. The amendment to the By-Laws, Section 23, submitted at the last regular meeting of the Society, was taken up; the President, as chairman of the "Committee on a Revised Constitution," presented a report thereon, and the proposed section was adopted instead of the one in force.

On the recommendation of the Board of Direction, the fee henceforth to be paid by Fellows,

under Article xxvi. of the Constitution, was reduced from $250 to $150.

The President, for the "Board of Censors to award the Norman Medal," reported:

"The undersigned, a Board of Censors to select from the papers submitted in competition for the Normal Medal, such one as in their judgment best meets the views of the founder and the true interests of the Society, beg leave to report, that the 'Memoir on the Construction of a Stone Dam,' a paper submitted without other mark of identification, is entitled to the Norman Medal for 1874. Julius W. Adams, President American Society of Civil Engineers; John G. Barnard, Colonel of Engineers and Brevet Major-General U. S. A."

The sealed envelope accompanying the paper named was opened, and Mr. James R. Croes, of New York, declared the successful competitor.

Mr. Alfred P. Boller, chairman of the committee on "Time and Place of the Seventh Annual Convention," made a report which was accepted. Communications from Mr. William P. Shinn, of Pittsburgh, and others, relating to the matter, were read. A discussion followed, and it was determined that the Convention should be held June 9th and 10th next, at Pittsburgh, Pa.

A report of progress from Mr. W. Sooy Smith, chairman of the committee on "Tests of American Iron and Steel," was presented and accepted; and to promote the objects in view the committee was requested to arrange for a general meeting of members of the Society, in Washington, during the next session of Congress.

Mr. Thomas C. Clarke, of the Committee on the "Means of Averting Bridge Accidents," stated that a report had recently been prepared by one member, which, from lack of time, had not been examined by others of the Committee, and under advice of his colleagues present, he would simply report progress.

Mr. John Bogart, chairman of the committee on a "Change of the Society's Rooms," presented a report which was accepted, the committee continued, and the Board of Direction instructed to secure more commodious quarters for the Society, at the expiration of the lease of the rooms now occupied.

The Committees—on a "Plan for the Increase, Maintenance, and Preservation of an Engineering Library and Museum;" on a "Comparative Examination of the principal Pumping Engines in Use;" on "Founding a Testing Laboratory;" on "Securing a National Recognition of the Society," and on "Railway Signals; severally made reports of progress.

IRON AND STEEL NOTES.

A Valuable Present to Lafayette College.—The Swedish Administration of the Iron Office has sent to Lafayette College a complete collection of the famous iron ores of Sweden, and their productions. The large boxes containing this collection arrived at Philadelphia last week in the ship Adolf Fredholm, and were delivered to the college by the Custom House officials, free of charge. This extensive and valuable collection is a duplicate to the one given some years since to the Royal School of Mines, in England, by the Swedish Government. It will be of special value and interest to the iron masters of Pennsylvania, and the college authorities intend to make it accessible at all times for their examination. We understand also that the professors of Lafayette are selecting from the duplicates in the college cabinets a complete collection of American ores, to be presented to the Swedish Administration in return for the one received by them.

Improvements in Furnaces and Processes.—Puddling apparatus is the object of improvements claimed by Sir J. G. Newton Alleyne, Bart., of the well-known Butterley Ironworks: these relate to partial rotary furnaces, such as are constructed with a revolving basin as a bottom, in combination with special rabbles for use in connection with the same. The bottom is made double, carried and rotated by a hollow shaft, within which a pipe is fixed with jets, for conveying water into the hollow space of the bottom, to play upon and cool the upper shell thereof, which forms the bottom of the puddling furnace; the water is conveyed away by a suitable outlet at the bottom of the tubular shaft. The rabble is made to stir the molten metal more effectively by means of a rotary or reciprocating action, suitably communicated to it, and is formed with a number of tines projecting from the stem down into the molten contents of the rotating basin.

Messrs. W. Blackett Haigh and A. Bleasby, of Oldham, have improvements in the construction of cupolas and furnaces for melting iron and other metals, such as are formed with chambers or receivers for the metal as run, and provided with an outlet flue into the atmosphere for the spent combustion products. Their proposal is to utilize these waste gases, by returning the heat and flame to the interior of the cupola or other furnace, partially to aid in melting the metal; and the apparatus consists of one or a number of tapered vertical pipes communicating with the receivers or chambers, and connected with a similar number of inclined or horizontal pipes conducting to the interior of the furnace, and they claim hereby to avoid the nuisance at present created, and at the same time keep cleaner the inside of the cupola or other furnace.

Improvements in the iron-smelting process and appliances are claimed by Mr. W. A. Lyttle, engineer, of The Grove, Hammersmith. As regards the charge, the inventor proposes to pulverize the ore and fluxing materials with a certain proportion of carbonaceous matter, and incorporate the whole by means of hydraulic cement into solid masses or lumps, like concrete or mortar. These blocks are then placed in the ordinary smelting furnace, in layers alternating with such a proportion of ordinary or other fuel as may suffice in conjunction with that contained in the blocks to effect the complete and thorough reduction of the ore incorporated therewith. As regards the smelting furnace itself, he provides a supplementary fuel or combustion chamber, exterior to the furnace, with an opening into the furnace opposite the blast-pipe nozzle, whereby bituminous coal, coal dust, or other suitable fuel may be employed, in quantity readily regulated, to be burned under the impact of the blast and supply heat; and the fuel chamber is provided with a feed-hopper, rod, and alarum, to indicate when the fuel requires to be re-

newed therein, by the descent of the rod, as the fuel is burnt away, acting on a bell.

Messrs. S. Newton, of Dudley, and C. Newton, of West Bromwich, introduce improvements in the construction of puddling furnaces for the manufacture of iron and steel; consisting in means for the maintenance of a continuously flowing current of water to keep the bed of the furnace at a low temperature and prevent injury by the heat. For this purpose wrought-iron U-shaped pipes are imbedded in the cast-iron plates forming the bed of the puddling furnace, or similar pipes are formed therein in the casting process; the ends of these wrought-iron pipes or cast-iron cavities are united by suitable junction pieces, and the continuous channel, formed in the bed of the furnace thereby, is formed preferably in a zigzag or tortuous course, so as to obtain a considerable area of cooling surface.—*Iron.*

RAILWAY NOTES.

RAILWAYS IN EUROPEAN TURKEY.—The opening of another section of the Salonica and Uskub Mitrovitza railway—a line now approaching completion—is an event of great importance, not only as regards the inhabitants of the fertile, but little known Turkish provinces through which it runs, but also for us, says an English exchange, inasmuch as, when the main line shall have been completed, and the proposed junction with the Austro Hungarian lines effected, it is by no means improbable that Salonica may become the most convenient port of embarkation for India and the East. The distance from Salonica to Mitrovitza, on the borders of Bosnia, is 361 kilometres, of which 25, making a total of 268, have just been opened; and the contractor, Signor Bariola, calculates on being able to complete the line to Mitrovitza by the end of August. The railway, in its course, is carried through 11 tunnels, of an aggregate length of 1,400 metres, and by means of 47 bridges (the total length of which extends to 2,545 metres) over wide streams which have not for ages been spanned by man. The rails have been obtained from England and France; the rolling stock has been furnished by Belgium and Germany; and the scientific and working staff, including engineers, masons, carpenters, smiths, etc., have come from Italy, with the contractor, Signor Bariola, who is himself an Italian; while the common kind of labor has been provided by the inhabitants of the countries through which the line has passed. —*Iron Age.*

ENGINEERING STRUCTURES.

IMPROVEMENT OF THE LOIRE.—The great proposed work of the amelioration of the river Loire from Nantes to the sea has been reported on by a commission of four inspectors-general. The report declares the condition of the river to be intolerable; there is only 4m. 30 depth of water, at the low tides, and often not more than 3m. 60, and the navigation demands 6m. 50. Two plans were before the commission—one by M. Carlier, who proposes a lateral canal, the cost of which he estimates at 89,000,000 fr.: the other, by MM. Partiot and Lechalas, who declare that the river may be improved and dredged to the desired depth for 49,000,000 fr. The execution of this work has been under discussion for years; in 1851, especially, plans were drawn up for a system of dams to narrow the bed of the river, and convert the sides into reservoirs for the purpose of scouring it. A portion of this scheme was carried out between 1859 and 1864 with good effect; but in 1872 the high tides reduced it to the lamentable condition it is in at present. M. Carlier proposes to cut a canal to the right of the river, 30 metres wide at bottom with a profile varying from 4 base to 1 in height in the rocky portions, to 5 to 1 in the soft mud. His plan is to execute the canal in three portions, each communicating at both ends with the river by means of locks, so that they may be executed and used separately. The three sections are—the river portion proper, 12,400 metres long; the intermediate portion, 25,900 metres; and the maritime portion, 12,500 metres; in all, more than 30 miles. He proposes to construct the middle section first, hoping that possibly the upper part of the river may be deepened by dredging, and thus the upper section of the canal rendered unnecessary; which hope, however, is not shared by the chief engineer, M. Watier. It must be added that whatever plan is adopted of obtaining a depth of more than six metres of water, and thus admitting large vessels, will require the construction of a basin at Nantes, which is estimated by M. Carlier to cost 27,0 0,000 fr., and is included in his total of 89,000,000 fr. The commission considers the estimates of M. Carlier as untrustworthy, and say that in such works the unexpected generally exceeds what was calculated, and the proprietors of the lands contiguous to the river complain that the canal will prevent the high tides from flooding and fertilizing the low grounds on the right bank of the river, thus reducing the value of rental from 200 fr. per hectare to, perhaps half that amount. The commission believes further that the bad composition of the soil would probably cause the excavation to turn out a "bottomless gulf to swallow up the Government money," and report against the project. The particulars of the plan of MM. Partiot and Lechalas we must defer for the present.—*Iron.*

ORDNANCE AND NAVAL.

TRIAL TRIP OF THE "CITY OF TOKIO."—The engineers' trial trip of the Pacific Mail Company's steamship City of Tokio, Capt. J. Maury, was made on Monday, Oct. 19, and was in all respects a decided success. She is the exact counterpart of the City of Peking. It is almost needless to say that both ships reflect the highest credit upon all parties concerned, and excite the warmest admiration of all who see them.

The City of Tokio left her dock at half-past ten, having on board about two hundred and fifty invited guests.

Owing to a strong northwesterly wind which was blowing at the time, a considerable delay was occasioned in starting, but at a little before eleven o'clock her engines began to move, and from that time until her return to the city the bell was not once rung for stopping, except in testing her engines and turning the ship, to ascertain how she backed and how she went ahead. Her route was

down to the Southwest Spit, out to sea, round the Light Ship to Squan Beach, and thence back to the city, which was reached between five and six o'clock. Nothing occurred during the entire trip to mar its pleasure. The engines worked admirably and were praised in loud terms on all sides. She was not speeded at any time during the trip, and the throttle-valve was not more than half opened. The best time made, as reported, was at the rate of fifteen knots over a measured mile, while making fifty-three revolutions. The engines were reversed in fifteen seconds. The turning in a full circle occupied a little less than twelve minutes. It was noted that probably no ship ever had on her trial trip so many professional engineers, or so many competent to form a critical judgment, and also that their criticisms were all highly favorable to her arrangements and workings.—*Nautical Gazette.*

BOOK NOTICES.

No. 11 SCIENCE SERIES.

THEORY OF ARCHES. By Professor W. ALLAN. Price 50 cents. New York: Van Nostrand.

This is a small but very convenient and comprehensive compendium of Prof. Rankine's chapters on the subject of arches, but more thoroughly explained and amplified. The book, as of necessity it must, infers a considerable mathematical knowledge on the part of the student, as far as conic sections and the differential calculus. We hope that this fact will not remove it out of the reach of many civil engineering students, more especially of the rising generation. The subject is exhaustively and clearly considered, all cases of variety of loading being, as far as possible, given. The estimation of the various forms of arches is very clearly introduced by first using the converse of each case—a string loaded in all varieties of manners, the pressures resolved and analyzed, and the form of curve which the string will take deduced and expressed by a suitable linear equation. In this way, the curve of a string loaded in any given manner being arrived at, it is a simple deduction that an arch in its ultimate shape to resist similar but opposite strains must have the same curve. In conclusion, we will give this little handbook the rare credit of not being unnecessarily discursive or wearisome, containing the necessary information to construct, under almost every condition, and no more, so that he who buys it gets the maximum amount of information on the definite subject, with the least quantity of padding, for his money.—*Iron.*

In this little treatise, which forms the 11th No. of the publisher's "Science Series," the author takes as his model the method adopted by the late Professor Rankine of investigating the subject, and introduces amplifications and explanations of his own. He, in the first place, makes the ordinary assumption that the arch may be represented by a chain or cord, and the strain theoretically investigated. By reversing the cord, and supposing it replaced by a thin metal strip capable of resisting a compressive strain in the direction of its length at any point, we obtain the "linear arch, or rib." Practically this particular description of arch has no existence, but it forms the basis from which the form of equilibrium for actual arches of construction may be determined. Thus, knowing the form which would be assumed by the linear arch under any given disposition of load, the line of resulting pressure can be found for a real arch. The author investigates also the principle of the geostatic and hydrostatic arches. We think a division of the contents of the little volume into chapters or sections would facilitate the perusal of it.—*The Engineer.*

QUANTITIES AND MEASUREMENTS. HOW TO CALCULATE THEM. By ALFRED C. BEATON. Fourth Edition. Revised and Enlarged. London, 1874. For sale by Van Nostrand. Price 60 cents.

Weale's series of handbooks have long been favorably known to many sections of the scientific and industrial public; and among the best and most useful of them may be classed this of Mr. Beaton's, which relates to all kinds of artificer's work, and is calculated, from the easy, methodical, and ready formulæ which it contains, to be equally serviceable to the experienced workman and the apprentice, to the master artificer, the surveyor, and the architect. The present edition contains, over and above what was to be found in previous ones, carefully prepared lists of prices for work in all branches of the building trade.

EARTHWORK TABLES. By JOSEPH BROADBENT and FRANCIS CAMPIN, Civil Engineers. London, 1874. For sale by Van Nostrand.

These tables, which were in the first instance prepared by the authors for their own use, and have therefore passed the test of actual experience, show the contents in cubic yards of embankments, cuttings, etc., of heights and depth up to an average of 80 feet, in order to facilitate the accurate determination of earthwork quantities in estimates for permanent work; and we have no doubt that they will be found useful by contractors and others. They are printed in a clear and legible manner, and full instructions for their use are prepared.—*Iron.*

LA GEOLOGIE DE LA FRANCE.—By M. AMÉDÉE BURAT, Professor of Exploration of Mines in the Central College, France. Paris, 1874. For sale by Van Nostrand. Price $6.40.

This interesting work contains special notices and descriptions of every region of France. Nevertheless, we must say, a certain acquaintance with the study of rocks is required, in order to completely understand M. Burat's work and profit by its perusal. The author has divided his work into six chapters, and adopted an excellent plan to embrace at once the whole geology of the country. At the commencement he gives, under the title of a geological chart, the description of the manifestations of each of the phenomena which have overturned the ground at the different epochs of disturbance; then he follows each geological formation in the order of the scientific classifications, studying each of them in the different regions where they may be met with, and tracing them from remote ages downwards. He passes in review, each in a separate chapter, the mountainous parts of the country, where are found granitic lands mixed with transition lands, and the porphyritic and volcanic lands, thus closing the series of primitive rocks. The three last chapters are dedicated

to the succeeding regions, in which we are more especially interested, where the coal fields are situated (or the secondary formation), which are placed immediately after them in the geological order, and lastly, the tertiary formation and alluvial lands, which complete the earth's crust as it appears in France.

SHORT LOGARITHMIC AND OTHER TABLES INTENDED TO FACILITATE PRACTICAL CALCULATIONS, AND FOR SOLVING ARITHMETICAL PROBLEMS IN CLASS. London, 1874. For sale by Van Nostrand.

The dozen pages before us contain the logarithms of numbers as far as 1600 to five places of decimals, together with various short tables constantly used by engineers in their professional calculations. The tables of "Useful Multipliers," and "Multipliers for conversion of English and French measures," will be found valuable, and will very much facilitate that description of labor which is not only entirely unprofitable, but of all others the most liable to error. The contents comprise tables of the weight of the ordinary constructive materials, squares and cubes, and areas of circles. —*The Engineer.*

TABLES FOR TRAVELLERS; ADAPTED TO THE POCKET OR SEXTANT CASE. Compiled by ADMIRAL BETHUNE, C.B., F.R.A.S., F.R.G.S. Second Edition. Edinburgh and London: W. Blackwood & Sons.

The handy little pocket companion before us is intended to supply the want of books of reference to mariners or scientific travellers under obvious contingencies. Bailie Nicol Jarvie sagely observed that even a Glasgow magistrate could not expect "to carry the comforts of the Sautmarket at his tail" in Rob Roy's country, and members of both the useful classes which we have named, often find themselves in positions in which a library of reference is out of the question. Under such circumstances Admiral Bethune's booklet, which may be stowed in the sextant case or waistcoat pocket, supplies the want of many volumes, containing, as it does, tables and other formulæ to assist in finding the sun's right ascension and declination, lunar and planetary corrections, tables, and logarithms, methods for finding the latitude and time, and solutions of quite a number of other and almost equally important problems.

IRON AND TIMBER RAILWAY SUPERSTRUCTURES AND GENERAL WORKS. By J. W. GROVER, M. Inst. C. E. London. For sale by Van Nostrand. Price $17.00.

This work consists of some forty lithographs of timber and iron bridges, together with some specifications for ordinary railway works and permanent way. We cannot congratulate the author upon the style of his designs. With one or two exceptions of timber superstructures, all the designs—which are of the open web type—have three sets of bars in the web, one in a vertical and two in a diagonal direction. Every scientific engineer is now well aware that one of these three sets is superfluous, and its employment simply signifies so much waste of material. Timber trusses, and those of iron on a very small scale, such as gantries, are exceptions to this rule. Gibbs and cottars, in our opinion, do not form suitable connections for bridges of spans of 40 ft. Mr. Grover confines himself strictly to girders of only one type—those with open webs and parallel top and bottom flanges—if we except a couple of pages devoted to skeleton elevations of plate girders. The volume is well printed and the lithographs clear, especially the lettering and dimensions. A glance at page 23 will best show the manner in which the text is arranged. We question the good taste of an author including in what are intended for model specifications one of his own "steel spring washers" as an essential item of permanent way. It is a common mistake in getting up books to crowd too much matter in too small a space. In the volume before us it is manifest that the opposite extreme is equally possible.

MISCELLANEOUS.

THE GRAPHIC REPRESENTATION OF STRAINS IN BEAMS.—Mr. John Neville, C.E., M.R.I.A., read a paper at the meeting of the British Association on "The Vertical Shearing Stress of Beams and the Point of Maximum Bending Moment," explaining a new method of discovering the stress by graphic methods. The following is an extract of the paper:—

The vertical shearing stress of a beam at any point is known to be equal to the weight on the next pier less the weight lying between this pier and the point. It is generally represented graphically for each point by ordinates to the line of beam on one side only. Now, as the sum of these stresses must be zero, those on one side being positive and those on the other negative, the proper graphical representation is to show them according to these signs above and below the line of beam. This leads to a simple geometrical construction for finding the shearing stress when the beam is loaded in any way with a number of weights, single or distributed. Find the line of shearing stress for the beam itself, then using this line plot on it the line of shearing stress for the first weight, making the ordinates vertical to the line of beam itself. Plot from this second shearing line a third shearing line for the second weight, and so on. The shearing line last found gives the stresses arising from the weight of the beam and the weights for each point. The construction gives the line of shearing stress at each step, and for each weight also.

When the shearing is a maximum the bending moment is zero, and where the shearing stress is zero the bending moment is a maximum; consequently, that point where the line of shearing stress intersects the beam is that of the greatest bending moment.

The areas between the line of beam and the line of shearing stress above and below are equal

AN esteemed Paris contemporary in concluding a review of the French railways, says, that "the Suez canal, the St. Gothard tunnel, and the series of European railways, are evidently directed against France, the object being to take from her the transit business of England," and that it is the duty of France to establish such relations with England that the advantage of shorter distance may turn to the profit of the former, and preserve to her the transit which makes the prosperity of the great lines of railway.